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Information Requirements in Future Medical Operations

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In the future, medical support for Naval Expeditionary Forces will face different and perhaps more difficult challenges. Under traditional doctrine, medical support relies heavily on placing its assets on the beach, after an initial buildup of forces clears the area of enemy threats. In future operations, however, under the Operational Maneuver From the Sea Concept, there will often be no buildup of forces at a beach landing site. The warfighters will operate with great force and at a pace that allows them to dictate the terms of the conflict. They will act decisively, at multiple locations if called for, over large distances, keeping the enemy reactive and ineffective by applying strengths to enemy weaknesses. Small units will move independently, exploiting weaknesses that could not have been predicted before battle. This research memorandum addresses two questions: What are Navy medicine's alternatives for handling the greater need for information and communication in the new battle environment? And What are Navy medicine's minimum information and communication requirements for doing its job in such taxing conditions?

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Contents

Summary

Overview

New concepts of operations for the Navy and Marine Corps, such as Operational Maneuver From the Sea, will complicate the task of medically treating warfighters. Future warfighters will be dispersed more widely, will move greater distances at faster speeds, will react more independently, and will likely be more interspersed with the enemy. Although there might be fewer casualties, evacuating the injured will be more complicated, and troops might have to wait longer before being moved to fixed medical facilities.

This memorandum addresses the following questions:

- What are Navy medicine's minimum *information requirements* for fulfilling its roles in these new circumstances?
- What information and communication technologies can deal with this new, more challenging environment?

To answer these two questions, we describe how the Navy and Marines of the future will fight; next, we present several alternative medical system configurations for handling future battlefield casualties. We then perform three essential tasks:

1. List each medical configuration's information requirements.
2. Outline communication systems to carry the required information.
3. Develop technical specifications for these communication systems.

The requirements that we identified can be used to help select among several technologies, even those not yet developed. We take these requirements further and describe, in layman's terms, three systems that meet Navy/Marine Corps minimal information needs. In the last

step, we analyze the state of technology to fulfill naval communication requirements, including bandwidth and data rate requirements.

In these new combat environments, the mission of operational Navy medicine will continue to be the prevention,[1] evacuation,[2] and treatment of combat injuries and disease and nonbattle injuries (DNBI). The most important factor in preventing combat casualties is ensuring that we win the conflict, so whatever information and communication technologies we present as requirements must be compatible with the warfighter's mission.

For the receiver, information is knowledge of a particular event or situation; it is also knowledge derived from sustained study or instruction. The first kind of information is immediate and can be received *during* the heat of battle. The second kind of information we call training—long-term knowledge that is learned by the receiver *before* a crisis takes place.

Information can reduce uncertainty in making decisions and contributes to the quality of decisions if it is the right type of information made available to the right people. Therefore, defining information requirements requires the enumeration and clarification of what decisions medical personnel will make or influence. These decisions involve Navy medicine's missions of:

- Preventing casualties
- Locating
- Clearing and protecting
- Assessing, diagnosing, and triaging

1. Technically, prevention is a line responsibility, for which medical provides technical input.

2. Evacuation is also a line responsibility, but medical has a role in evacuation because (a) the corpsman plays a part in deciding whether evacuation is necessary for any casualty and (b) evacuation is intrinsically linked with efficient medical regulating and the ability to track casualties throughout the medical system.

- Treating and sustaining
- Evacuating, regulating, and tracking
- Providing medical supply.

Information systems

If medical taps into systems that the warfighter is developing, medical can focus its attention on three information systems in which it has a major and unique responsibility:

- Treatment[3]
- Evacuating, regulating, and tracking
- Medical supply.

Information can be of four basic forms: data, voice, image, or video. Technically, all four forms of information are data. But as we define these kinds, *data* produce several distinct types of products, including e-mail, low-resolution graphics, text, electronic bulletin boards, and numeric streams. The streams might include data from personal sensors. In contrast, *voice* involves reproduction of a person's vocalizations, *image* refers to higher resolution graphics, and *video* means that images move. These last three information forms are, for the most part, "real time" and imply immediate interaction between different sites. Data, on the other hand, can be "stored and forwarded," with more lag time permitted between transmission and receipt of information.

Treatment

Training is the most important kind of information for treatment because it weighs nothing, takes no space, and can be applied without waiting for communication hookups. These characteristics are especially important for those who have the best chance to save the lives

3. This system supports medicine's treating and sustaining; assessing, diagnosing, and triaging; and some aspects of the prevention functions.

of those involved in ground combat: the infantrymen and unit corpsmen who provide initial treatment.

To augment training, *voice consultation* and *patient information data systems* are sufficient to support treatment decisions from the point of injury up to but not including the surgical company. At the surgical company, we found the need for enhanced teleconsulting and telementoring. The addition of *video and/or image transmissions* at the surgical company could compensate for the fact that specialist physicians are no longer assigned there. Another important feature of these systems is that information should mainly be requested by the personnel treating casualties, resulting in a "pull" of information: Caregivers should be able to initiate communications without getting unsolicited advice.

Evacuation and medical supply

For evacuation and medical supply systems, sufficient information can be supplied by a data system with voice backup. The evacuation, regulating, and tracking system would provide access to several electronic bulletin boards and a near-real-time picture of the overall situation and individual casualty movement status. The supply network would rely on data to give everyone access to an electronic bulletin board that provides in-transit visibility.

Communication systems—cost and feasibility

Finally, we considered the feasibility, costs, and technical characteristics of present and likely future communication systems to supply these information requirements. We concluded that:

- It is within the capability of today's ATF communications to supply medical's information requirements for low-rate data; this is not true for voice requirements.
- If the surgical company had a dedicated link via INMARSAT, it would not strain capabilities to provide image transmission capability and video consultation (without full-motion video) at the surgical company. Judicious use of these capabilities is required to prevent overloading the communication systems.

- Given practical constraints, the surgical company is the first place where image or video could be used successfully. Navy medicine has two options at the surgical company. The surgical company could use "store and forward" still image, e-mail, and voice communications to support consultations. A much more costly option would be to supply full-motion video.
- It would severely strain communication resources to provide extensive, unlimited voice systems down to the unit corpsman level. The solution would be to restrict voice consultations, improve training to reduce reliance on consults, and utilize inexpensive data capabilities, such as e-mail.

The communication requirements we specify here might need to be altered drastically if current medical technology makes major leaps. For example, advances in treatment of head injuries might require that a neurosurgeon consult with corpsmen; on the other hand, a portable expert system to help corpsmen diagnose casualties might decrease information requirements.

Context

Our analyses of information and communication systems indicate that, *with proper planning*, the estimated medical communication requirements can be met. Nevertheless, human nature under stress tends toward overreliance on communication systems—particularly voice communications. *To avoid system overload*, there will need to be training in communications discipline. *To avoid information overload* to individuals, information preprocessors and interfaces must be developed to present only relevant data in an organized fashion.

We note that future exercises and wargame efforts, such as CSS Enterprise, *Vanguard '96*, and the Naval Expeditionary Concept of Casualty Care (NEC^3) workshop, will provide an indispensable process to refine information and communication requirements.

Chapter 1: Background and issues

Background

In the future, medical support for Naval Expeditionary Forces will face different and perhaps more difficult challenges [1]. Under traditional doctrine, medical support relies heavily on placing its assets on the beach, after an initial buildup of forces clears the area of enemy threats. In future operations, however, under the Operational Maneuver From the Sea (OMFTS) Concept, there will often be no buildup of forces at a beach landing site—the LCAC, AAAV, V-22, and other assets of the future will allow the warfighter to focus on operational objectives without interruption, and achieve them rapidly. The warfighters will operate with great force and at a pace that allows them to dictate the terms of the conflict. They will act decisively, at multiple locations if called for, over large distances, keeping the enemy reactive and ineffective by applying strengths to enemy weaknesses. Small units will move independently, exploiting weaknesses that could not have been predicted before battle.

Issues

These characteristics of future battles can make medical support more difficult in several ways. Casualties are likely to be highly dispersed, with a large percentage of injured personnel interspersed with the enemy. Before the battle, it will be more uncertain where casualties are likely to be, and what kind of injuries they will sustain. Under these conditions, information flow and communications will be critically important to Navy medicine.

This research memorandum addresses two questions:

- What are Navy medicine's alternatives for handling the greater need for information and communication in the new battle environment?

- What are Navy medicine's minimum *information and communication requirements* for doing its job in such taxing conditions?

We define information in two ways. First, it is knowledge of a particular event or situation. Such information can be carried over electronic communication systems. Second, information can be knowledge derived from study, experience, instruction, or training. The first kind of information constitutes *immediate* knowledge and is received during the heat of battle; the second kind is *long-term* knowledge, assimilated before a crisis takes place.

Communication is the movement of electrons between nodes. They can carry information that is translated into different information forms: data, voice, image, or video.

As a study for N093M, this research crosses Navy/Marine Corps lines of distinction. It deals primarily with levels of medical care from nonsurgical stabilization to surgical stabilization—what we traditionally have labeled echelon I, up to but not including the Primary Casualty Receiving and Treatment Ships (PCRTSs) or other echelon III facilities.[4]

We estimate the capacity required to support medical information and communications among medical care providers in the field (including voice, data, image and video requirements). We do *not* include in our estimates the requirements for medical communications from ship to ship and between ships and echelon III and above providers. GTE recently completed the Pacific Command (PACOM) Health Care Bandwidth Requirements study [2], which addresses these requirements. More specifically, the GTE study considered the requirements for medical communications between health care providers starting at the PCRTSs through CONUS tertiary care facilities (echelon V). The GTE study did not include communication requirements for field medical support, and it focused only on the high-capacity portion of the medical network, ignoring the low-capacity portion, an essential piece of our recommended network for the

4. Although the PCRTSs are considered echelon II facilities, they can function as echelon II+ or echelon III facilities with certain augmentations and upgrades. In this paper, we assume this higher level of care is provided by the PCRTSs (LHAs and LHDs) in several circumstances.

field. Both the GTE study and our study used the same methodology and similar scenarios in estimating the communication requirements. For all of these reasons, the studies complement each other well. Together, they address the medical communications for all levels of care with minimal overlap.

This memorandum also does *not* deal with peacetime uses of telemedicine technologies because to do so would overlap substantially with projects that are already under way at Advanced Research Projects Agency (ARPA) [3], Medical Advanced Technologies Management Office (MATMO) [4], the Theater Medical Information Program (TMIP) [5], the Corps Level Theater Medical Information System (TMIS) [6], the TRANSCOM Regulating Command & Control Evacuation System (TRAC^{2}ES) [7], and NHRC [8].

Approach

In this memorandum, we examine the *information and communication requirements* for medical in the future, looking first at what is needed, rather than looking first at technologies. We have taken this approach to help develop a set of minimal requirements instead of a set of desired technologies.

To determine future information requirements, we found it necessary to first:

- Describe the future battlefield Navy medicine will face
- Identify alternative medical system configurations for handling future battlefield casualties.

Once we understood the battlefield of the future and its implications for operational medicine, we proceeded to:

- Determine medical information requirements
- Define a nominal communication system to carry the required information
- Outline technical specifications of these medical communication requirements.

Future battlefield

To understand the future battlefield and its implications for medical, we made use of an earlier CNA study [1] and interviewed a wide range of members of the Navy and Marine Corps warfighting community. We translated future battlefield characteristics into consequences to determine how medical must do its job. This task provided specifics about the future battlefield, including speed and availability of transportation for medevac, architecture of warfighters' communication systems, and the speed of alternative organizational changes.[5] These characteristics are the future parameters within which military medicine must operate.

Alternative medical system configurations

Given the radical changes in the battlefield, the operational medical system of the future will most likely be different from the current echelon system. Before developing information requirements, one must have a concept of how the future medical system will be structured. We explored how different setups can deal with future battlefield situations. These configurations run along a continuum, depending on the size of the footprint allowed for medical, and the strategy that Navy medicine chooses to treat and evacuate casualties. We describe several different sample configurations for providing care.[6] The three examples of alternative system configurations that we focus on are options for supporting:

- A limited operation involving completely sea-based combat service support and only one large amphibious ship capable of supporting surgical procedures

5. We worked with the Marine Corps Commandant's Warfighting Lab, and other military commands, to provide a reality check to our range of values. With the benefit of CNA documentation of past Marine Corps operations and consultation with MCCDC and CNA analysts in warfare areas, we outlined the types of characteristics and likely situations that might occur on the future battlefield.

6. Among our alternatives are the capabilities of the present system's standard configuration, including the restructured medical battalion that went into effect 1 October 1995 [9].

- A transitional operation with slightly more medical presence on shore and three large amphibious ships
- A sustained operation that allows for all the currently used assets in today's consolidation phase of amphibious operations and seven big-deck amphibians.

Medical information and communication requirements

Based on these potential medical structures and the characteristics of the future battlefield, we identify the current and likely needs for medical information and communications to aid in the care and movement of casualties. The requirements are general and can be used to help select among several technologies, even those not yet developed.

We take the development of general requirements one step further and describe, in layman's terms, three systems that meet the minimal medical information needs of the Navy and Marine Corps. And, finally, we analyze the state of technology to fulfill the communication requirements we specified. This analysis provides specifics about future communication configurations, including speed and bandwidth characteristics.

Chapter 2: Characteristics of future battlefields for medical

This chapter provides an overview of the future battlefield that serves as essential background for developing the information requirements of medical units. We describe the following:

- Future operational concepts, such as Operational Maneuver From the Sea (OMFTS), and how they are different from traditional amphibious operations
- Likely changes in Marine Corps organization
- The transportation that will be available for carrying casualties
- Expected changes in Marine Corps and Navy information and communication systems.

Predicting the future is a risky business. The ideas expressed here represent our best estimates of what the future might hold, based on our research. Many of the concepts presented here are exploratory. Although we present ranges of values, many of the numbers might change as a result of future modifications of policy, strategy, and equipment. But, determining the potential parameters of the future battlefield is an essential step for determining medical's future information and communication requirements.

We have used a variety of sources to develop our description of the future battlefield, including the following:

- Discussions with members of the Commandant's Warfighting Lab
- 1st Force Service Support Group (FSSG) at I MEF[7]

7. The Commandant's Warfighting Lab engaged FSSG at I MEF to do further detailed planning for the CSS side of future Marine operations.

- Marine Corps publications
- Naval Warfare Publications
- OMFTS War Game Final Report [10]
- CNA publications concerning wartime planning for combat service support (CSS).

An overview of future operational concepts

Traditional amphibious operations typically involve taking and securing the beach, followed by movement to, and action on, targets inland. Figure 1 shows the operation's phases of initial assault, buildup, and consolidation [11]. Historically, these initial phases are the most costly in terms of deaths and injuries.

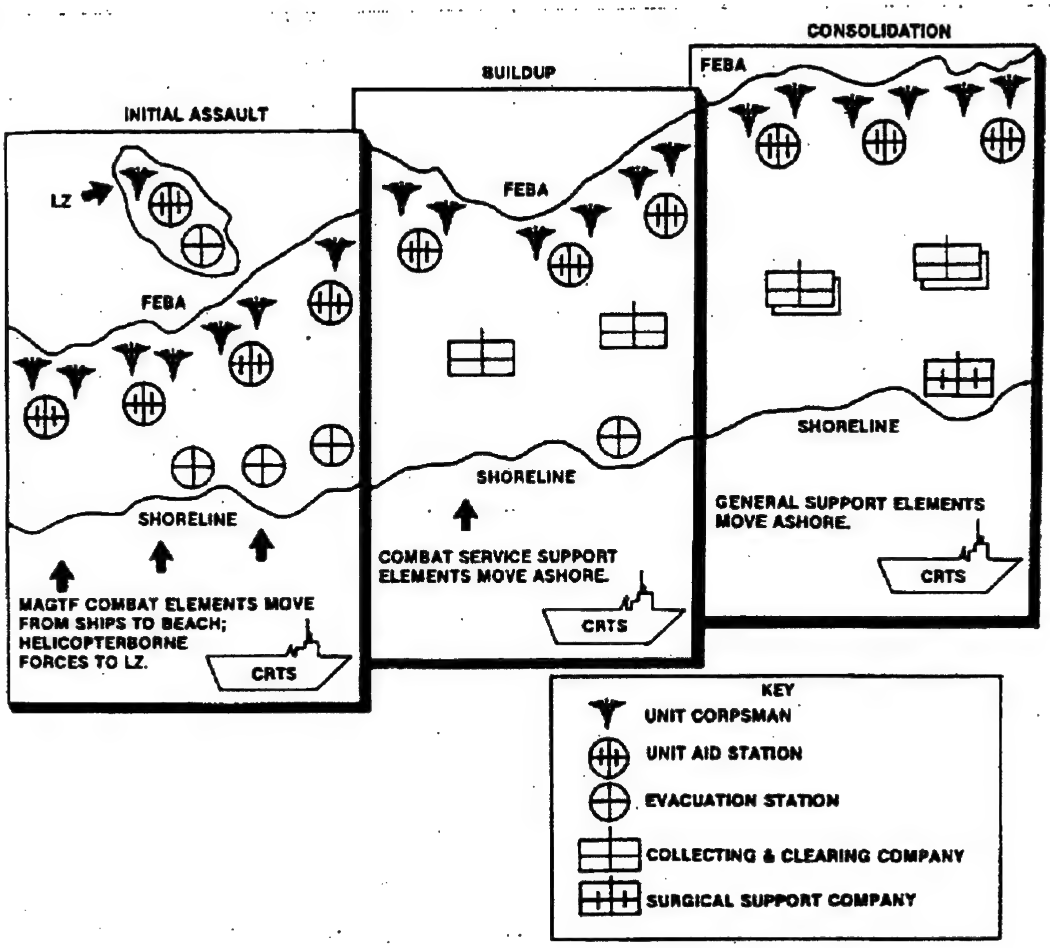
The concept of OMFTS will change the initial assault on the beach. This is expected to decrease the casualty rate associated with amphibious operations in the future. As described in *Concepts and Issues* [12], OMFTS involves the ability to move quickly, continuously, and over large distances. CSS is often sea-based under OMFTS, and there is less direct buildup ashore. The success of OMFTS depends on advances in speed, mobility, communications, and navigation.

Sea Dragon, the current focus of the Commandant's Warfighting Lab, builds on concepts of OMFTS, pushing these concepts to develop new tactics, techniques, procedures, and organizations that improve the Marines' capabilities.[8] The Warfighting Lab notes that, in the future, our enemies will have more lethal munitions and possibly greater ability to detect our forces. If they can sense a target, they can destroy or neutralize it. To counteract these greater dangers, the Marines will develop greater sensor capabilities, use more capable weapons, make

8. Members of the Warfighting Lab work on concepts for the long-term future of the Marine Corps; some of the lab's visions are exploratory. The Commandant's Warfighting Lab is responsible for coordinating concepts and technologies with the Marine Corps, industry, research labs, academia, and other services.

a smaller footprint, and be able to operate over a battlespace of greater depth and breadth.[9]

Figure 1. Stages of medical in a traditional amphibious operation[a]



a. Source [11].

9. Operating over greater depth and breadth is only one form of maneuver, and is *in addition* to the Marines' current capabilities. The dispersed battlefield is an experimental concept that the Commandant's Warfighting Lab will evaluate extensively in the coming year.

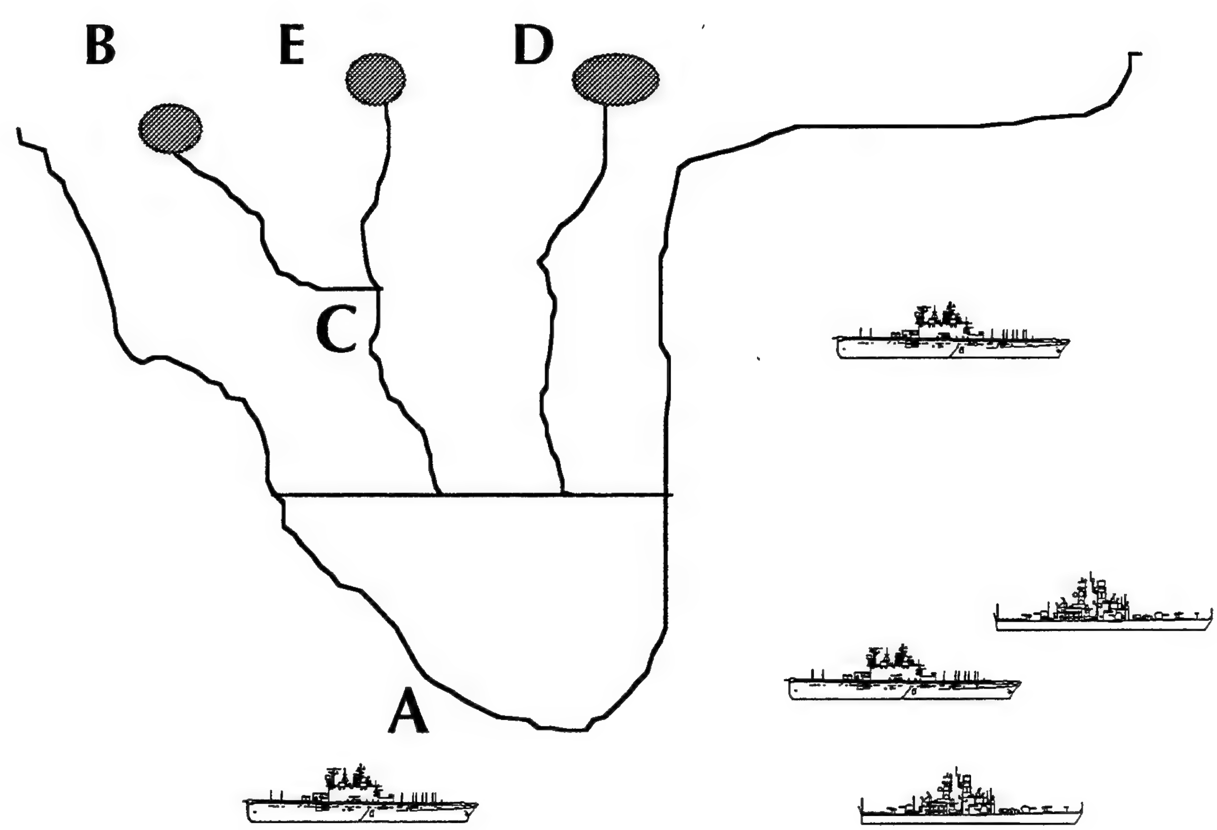
There may be no ground-based depots or hospitals on shore because this creates a vital area to defend—a weakness the enemy can exploit. In cases where there is no service support ashore, the nearest surgically capable platform may be a big-deck amphibious ship, such as an LHD or LHA. The warfighters will attack from over the horizon (about 25 to 50 n.mi. offshore), to distances as far as 150 n.mi. inland, to attack high-priority objectives directly.

Figure 2 gives an example of the kind of battle that might be fought in the future. Let's say that the primary objective of a battle is to control a weapon factory in the center of area E. In a traditional amphibious operation, Marines would move by landing craft and helicopters from the amphibious ships to a suitable nearby beach area (A). They would occupy area A, which would become the base for combat service support, such as supply, medical, ammunition, and fuel. This vital area would need to be protected as Marines maneuvered their way from A to the main objective area E. The enemy could bottle up our Marines around the beachhead, putting troops at significant risk and causing delay in reaching the primary target.

In contrast, with OMFTS, Marines would go directly to the main objective area E. Small teams of Marines might be flown to the perimeter of E. Those small teams would not directly attack E, but would control it by directing indirect fires—perhaps from ships. Fewer troops would be in harm's way, and the costly procedure (costly in terms of life and time) of taking a beachhead would be unnecessary. If Marines had to take a beach by amphibious assault, they would first "shape the battlefield" by knocking out primary avenues for enemy reinforcement. For example, small teams might direct fires to area C, to cut off a road that could be used by enemy reinforcements.

Although fewer casualties might be expected under future concepts of operation, ground units would be more interspersed with the enemy than under a traditional amphibious assault on A. These units might not have a corpsman, and they would be much farther from ships with surgical capability. The task of directing casualties to appropriate medical care would be made more difficult because of the distances involved, the greater dispersion of casualties, and the interspersion with the enemy.

Figure 2. Hypothetical Marine Corps operation



Under the new warfighting, the phases of an operation would be different. Whereas the initial phases of a traditional assault would have the heaviest casualties, the new concept would put fewer troops at risk, initially. It might not be until much further into the operation, if at all, that costlier infantry-on-infantry fighting would occur.

These characteristics of the new warfighting have the following consequences for medical:

- A possibly smaller number of casualties will be more highly dispersed than in traditional operations; hundreds of miles could

separate casualties. Therefore, the speed of transportation might be more important than carrying capacity.

- Casualties will be more highly interspersed with enemy; 50 to 200 n.mi. of enemy territory might separate casualties from the closest friendly forces. Therefore, the danger to casualties and those who evacuate them will be even greater than in traditional conflicts.
- A larger amount of CSS, including medical, will be sea-based. At times, all combat service support will be sea-based.[10]

All of these implications indicate that casualties may have to be treated and sustained in the field for extended periods of time, often with more limited medical personnel and equipment than is available today.[11] The issues raised are similar to those faced by search and rescue (SAR) missions today.

Marine Corps organization

Although the concept of OMFTS is in stark contrast to the traditional linear movement of amphibious battles, the Marine Corps will preserve its ability to apply traditional force maneuvers when they are necessary. The primary difference between the Marine Corps of the future and today's Marine Corps will be the emphasis on having smaller units of Marines, capable of operating independently for extended periods of time. The emphasis will be not on massing our troops but on massing our firepower on areas of tactical importance.

Under future concepts being explored through Sea Dragon, the Fleet Marine Forces would be a lighter and more mobile force. The basic maneuver element in light infantry units would be a platoon (of perhaps 21 Marines) rather than a battalion. These concepts go even further than OMFTS, focusing on the use of small independent teams (as

10. Lengthy or sustained operations ashore, in contrast, may dictate establishment of shore facilities.

11. One possibility for dealing with the longer wait periods would be to have sensors on infantrymen to transmit casualty conditions. We will deal with that possibility in chapters 5 and 6.

few as three Marines) that would gather intelligence and relay targets to the Commander and to supporting arms.[12] Table 1 shows the range of differences between the size of today's Marine Corp units and those envisioned for the future by the Warfighting Lab. This is only one option of various possibilities the lab is exploring.

Table 1. Approximate size of Marine Corps ground units: present and future

Ground unit	Number of personnel: Present	Future[a]
Team	4	3–4
Squad	13	6–13
Platoon	40	21[b]
Company	175	66–67
Battalion	About 900[b]	500

a. This is based on an experimental light infantry battalion. Not all Marine infantry battalions will be so organized. At least one-third of the structure would remain as heavy, according to the Commandant's Warfighting Lab.
b. Basic operational maneuver element.

What are the implications for medical? First, while ground units would still have their organic health service support, the corpsmen may not always be available to the troops. For example, the Warfighting Lab is considering the use of the three-person teams, which rely on speed, mobility, and stealth. When operating in this mode, ground units may be without a corpsman,[13] and all casualties (of equipment or personnel) will be evacuated from the battlefield.

12. Intelligence and targeting information will be passed to the Commander and indirect fire units simultaneously. At all times, the Commander will exercise ultimate control and may, as an option, authorize direct "sensor to shoot" mode.

13. In a three-person team, each member would have to be multifunctional and especially be required to function as an infantry Marine. The alternative to no corpsman is to have the corpsman train as a Marine, similar to what is done for special operations and reconnaissance platoons.

Second, the reduction in the size of the units and the emphasis on using indirect fire as the primary means of engaging the enemy imply that fewer Marines may be on the ground and at risk under the future concepts of operations. This should translate into fewer casualties. In fact, survivability and independence of ground troops becomes a primary focus of training and equipping the future Marine under the new warfighting concepts.

Third, those Marines or corpsmen who are responsible for caring for casualties will likely be far from a medical treatment facility and will need to take care of casualties for a longer period of time than previously. Therefore, corpsmen or Marines will need more resources to help them care for casualties, such as additional training in:

- Medical examination techniques
- Anatomy
- Advanced trauma life support.

They would also benefit from more advanced medical equipment and supplies for use in the field.

Transportation

Central to the operational concepts being developed under OMFTS are the enhanced capabilities that will result from the combination of the Landing Craft Air Cushion (LCAC), Advanced Amphibious Assault Vehicle (AAAV), and the V-22 Osprey tilt-rotor aircraft. This trio of mobility assets will allow the warfighter to operate at a much faster pace.

These capabilities allow the warfighter to increase the future battle space to up to 200 n.mi. from their ship base. The delivery and sustainment of troops across this vast battle space will often strain the available lift assets. In addition, the utility of ground transport will be limited by the distances, dispersion of the troops, and their interspersion with the enemy.

What does this mean for the ability to evacuate casualties? Although the V-22 will provide greater capabilities for fast medical evacuation, the availability of the V-22 and other air assets may be more

constrained because of the increased logistic demands placed on them as a result of seabasing logistics under OMFTS. In appendix A, we show the speeds and personnel-carrying capacities of craft that may be available as evacuation assets (see table 10). Because of the uncertainty that surrounds the operational concepts of the future, we have included any craft that has a reasonable troop capacity (10 or more) and, therefore, may be able to transport ambulatory patients, and possibly one or two litters.

Not shown in the appendix is the possible availability of unmanned air vehicles (UAVs) and small three-person ground transportation vehicles that may be organic to each three-person team (if the environment permits). These assets are being considered by the Warfighting Lab, which has discussed the use of UAVs for medical evacuation. The ability of the future three-person ground transportation vehicles to carry a litter has not been specifically discussed. This capability may be essential to allow the team to travel to a safe waiting spot for evacuation.

Finally, appendix A shows the availability of transportation assets to amphibious ships (see table 11). This gives an indication of how many primary evacuation assets (helicopters and LCACs) might be available for a given operation.[14]

Given these new concepts, it will not be enough to consider the availability of possible medical evacuation assets merely in terms of their numbers. Instead, one must consider the concept of operations being employed, the need to remain covert, the limitations on ground and surface assets due to distance of targets from sea base, and the stresses on air assets due to seabasing both troops and combat support services.

14. An Amphibious Ready Group (ARG) typically supports a Marine Expeditionary Unit (MEU) size of force, and will include either an LHA or LHD, and two cargo ships—typically an LPD and an LSD.

Information and communication infrastructure

Changes in command and control

The current command and control (C^2) structure supporting traditional operations is highly hierarchical. There are many echelons of command, even for a MEU-sized Amphibious Task Force (ATF) (e.g., CATF, CLF, BLT, company, platoon, and squad). Each command would routinely interact only with its immediate superior command, peer commands within the superior command, and subordinate commands. In the MEU, for example, the BLT would mainly interact with the MEU command element to which it belongs, the other two elements within the MEU (the Air Squadron and the MSSG), and the companies under its command.

In contrast, the concepts being explored under Sea Dragon require a C^2 structure that is flatter. A battalion commander may directly control a large number of individual teams. The teams, in turn, would report directly to the battalion commander vice the traditional platoon and company commanders. This difference in C^2 structures places different emphases on the information and communication architectures of the ATF.

In the current *information architecture,*[15] each echelon of command collects, interprets, and/or amplifies the information being passed up and down the chain of command. Thus, relevant information is injected into the architecture at each echelon. Also, information processing and filtering functions are accomplished throughout the entire C^2 structure. On the other hand, in Sea Dragon operations, intermediate commands together with their input may be absent.[16]

15. We use "information architecture" to refer to the collection of information processing and storage assets, their associated networks, and the processes they use to disseminate information.

16. The greater mobility of the Marine Corps forces makes it more likely that surgical companies will need to split and disperse. To maintain contact, it would be useful for portions of the surgical companies to be able to communicate to one another via some sort of network. We will deal with this possibility in chapers 5 and 6.

In this case, raw data are passed directly from the teams to the highest echelons.[17] Individual teams must have access to the information architecture to extract the information needed to fulfill their taskings.

As a result, the current *communication architecture,*[18] though well suited to the traditional C^2 structure, may not be adequate for the C^2 structure required to support future concepts of operations as described above. Currently, military frequency bands are divided into many narrow-band voice and data communication channels. These channels are assigned, on a permanent basis, to specific functions or nets. Because of the limited allocated bandwidth (for data nets) and the inefficient protocol for multiple access (for voice nets),[19] each net can only support a relatively small number of users.[20] This inefficient access protocol will prevent these nets from being able to support the Sea Dragon C^2 structure, where, for example, a battalion net may have to support the battalion commander, his staff, and all the individual teams. Further, this "stovepipe" communication architecture often creates communication shortfalls even when there is sufficient capacity to support all demands. This is because the architecture

17. Passing raw data to high echelons runs the risk of creating information overload at the higher echelons, as the Army has found [13]. Clearly, this is an issue that the Warfighting Lab will be addressing as it experiments with future concepts.

18. We use "communication architecture" to refer to the collection of communication assets and how they are interconnected to provide connectivity between users.

19. The current multiple access protocol for military voice net is similar to the Carrier Sensing Multiple Access (CSMA) protocol of computer networks. Using this protocol, a user would listen on the net to detect an ongoing conversation or the presence of the carrier wave. If neither of these is detected, the user would key on the transmitter (sending out the carrier wave) and speak into the microphone. Otherwise, the user would wait until the net is free. CSMA protocol studies have shown that its efficiency decreases as the number of net users increases.

20. According to an estimate from U.S. Space Command (USSPACECOM), there are a total of 808 UHF military satellite nets worldwide. Each net supports an average of eleven users [14].

cannot shift capacity of idle nets to support those that are being overloaded. As the number of net users increases, this problem gets worse.

Future infrastructures

As the warfighters embrace the Sea Dragon concepts, the information and communication architectures of future ATFs must change to adapt to the new C^2 structure. Here we present an overview of the infrastructures that are likely to be available to support an ATF in the 2000 to 2015 time frame[21] and their impacts on the medical community. This overview is a synthesis of the study's assessment of promising emergent information technologies, and an extrapolation of current and planned military information systems. The intention here is to provide only a broad outline of the basic characteristics of these infrastructures. Further detail is provided in appendix B.

In the future, an Amphibious Task Force operating anywhere in the world will be supported by a global information infrastructure. Using this infrastructure, task force commanders will be able to make information more readily available and accessible to all of its components. This infrastructure will be the outgrowth of today's Defense, Government, and National Information Infrastructure initiatives. Its capabilities will be largely due to the following interrelated developments:

- Global internetworks connecting a great number of data sources, local and metropolitan area networks, and users
- Improved organization and storage of information, such as data clearing centers with larger storage capacities that use advanced database technologies
- Improved means of retrieving information, such as global online directories—electronic "information agents" possessing artificial intelligence
- Increased accessibility of ever more capable computers to the mass market

21. This discussion is not limited to the Amphibious Task Force but is applicable to all future joint U.S. forces.

- Increased accessibility of advanced communication capabilities to the mass market.

One purpose of this study is estimating communication requirements, so we now focus on the last bullet—accessibility of advanced communication capabilities. In the future, all levels of commands of the Amphibious Task Force will be able to have access to virtually all of the ATF's communication assets. This increased accessibility will be a result of the following:

- Rapidly configurable equipment that allows dynamic allocation of assets based on needs and priority vice static dedication of assets to single uses for extended durations
- Improvements in miniaturizing electronic components and wider application of advanced digital processing techniques to increase equipment's reliability, capability, and security
- Wider applications of broadband digital techniques, such as Direct Sequence Spread Spectrum, that allow increased simultaneous access and security
- More useful equipment through durability, reliability, multifunctionality, reprogrammability, and low power consumption.

Increased availability and accessibility of information and communication assets will allow the development and maintenance of an accurate and up-to-date composite picture of the battlefield. This composite picture will be available on a need-to-know basis to all command echelons from individual teams to theater commanders. In other words, medical personnel will have direct access to both tactical and support databases, which will give them an improved battlefield awareness.[22] Medical regulators can use this enhanced battlefield awareness to rapidly locate, identify, and track casualties and medical support assets in the field. This information will afford medical regulators the opportunities to do the following:

- Efficiently use lift assets to medevac casualties to the ships.

22. This statement assumes that medical will be involved in integrating with the warfighters as systems are updated.

- Monitor the medical supply situation and forward additional supplies.
- Anticipate the need to reconfigure medical support to meet the ATF's needs.
- Anticipate the need to bring additional medical support into theater.

Increased access to advanced communication capabilities could also allow the medical community to deliver more sophisticated and effective care to previously inaccessible places, such as aboard ships and the forward edges of battlefields. These advanced medical techniques, which require large communication capacities, are collectively referred to as telemedicine.[23] However, the medical community must weigh the benefits of telemedicine against its costs in terms of communication capacities. This is necessary to avoid placing excessive demand on the ATF's communication architecture. Ultimately, it will be the warfighters who decide on the allocation and priorities for the use of limited communication assets.

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23. Telemedicine has been defined by Col. (Dr.) Benge, Chief of Technology Insertion, Directorate of Medical Studies and Evaluation, Surgeon General's office, as "the practice of medicine independent of time and space....We can put together a patient, the patient's clinical record, medical data, and whatever complicated services the patient needs, even though they may be separated by thousands of miles....Telemedicine melds [computer technology, communications technology, and medical practice] together to improve access to—and quality of—health care" [15].

Chapter 3: Alternative system configurations

The future battlefield has many implications for the way medical support will have to function. As a result, the medical system of the future may be significantly different from today's echelon system. In this chapter, we lay out examples of medical configurations that might be used to support the Marines in this new environment. Though it is not the purpose of this paper to develop a single future operational configuration for Navy medicine, it is important for us to address possible alternatives that could meet the wide range of operational challenges that medical will face in providing future field medical support. Our goal in doing so is to develop a framework for determining future information and communication requirements.

A continuum of care

We believe that future Marine Corps operations will range from the Sea Dragon concept of small, widely dispersed teams operating in unsecured territory to today's traditional MEF-sized amphibious operation with a significant support structure. Because Navy medicine will be called on to support many different concepts of operation, it is important that it have the capability to adapt its configuration to fit the operation. Navy medicine's capabilities must be viewed as a seamless continuum of configurations, able to support a wide range of situations through a spectrum of different medical strategies.

Operational situations

In defining this continuum, we found that the most important battlefield characteristic defining the structure of medical support for an operation is the size of the support footprint allowed. This is imposed on the medical community (as well as the rest of the support community) by the warfighter. It can range from no footprint (e.g., under the most austere Sea Dragon concepts) to a significant

footprint that would enable the use of all medical assets as currently configured (including unit corpsmen, Battalion Aid Station (BAS), shock trauma platoons, surgical company, and fleet hospitals).

Medical strategies

We also found that medical support varies not only by the range of situations (as defined by the warfighter), but also by a range of medical strategies for providing care. By strategies we mean the concept of how medical support is provided. This concept can range from "care-to-casualty" to "casualty-to-care." In the care-to-casualty concept, the highest level of care is brought as close to the site of injury as possible. This could be accomplished by bringing some combination of highly trained personnel, specialized medical equipment and supplies, and information and communication technologies as close to the site of injury as feasible. For example, we could bring a surgeon to the foxhole. Or, through telesurgery and with highly trained corpsmen assisting, we could transport the capabilities and expertise of the surgeon to the foxhole.

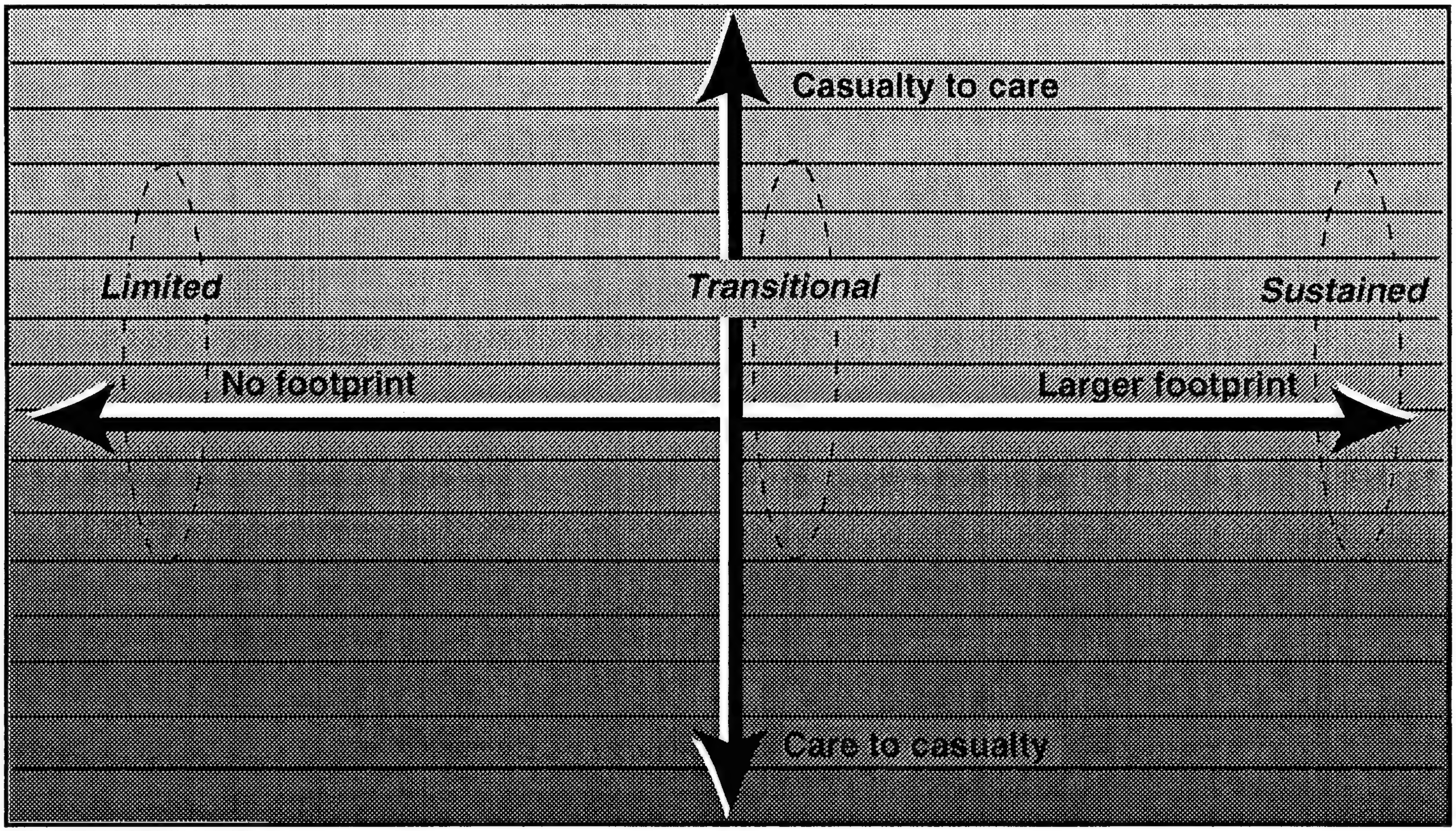
At the other end of the spectrum, medical could adopt a casualty-to-care concept, where little to no care is provided at the site of injury. Instead, the emphasis would be on immediate evacuation. The extreme here would be a "scoop-and-scoot" strategy, evacuating the casualties from the site of injury and delivering them directly to a definitive and rehabilitative care facility (what we currently refer to as echelon IV or V care).

The feasibility of a particular medical strategy will be heavily influenced by the warfighter. For example, the concept of operations, and the availability and priority of transportation assets will ultimately determine the degree that medical can rely on the scoop-and-scoot concept of care.

Defining a continuum of care

Figure 3 illustrates the two-dimensional space with which medical will function. On the x-axis, we portray the range of operational situations as described above, and on the y-axis we show the spectrum of medical strategies ranging from care-to-casualty to casualty-to-care. In this

Figure 3. Medical configurations: a range of situations and strategies



two-dimensional space, medical will have a continuous set of configurations that it is capable of providing for any given situation. That is, for any point along the x-axis, medical has a whole host of possible configurations that it can use to support that particular operation. This range of options is represented by the dashed oval intersecting the x-axis along a given segment. A particular configuration along this oval line may dominate the others, depending on such things as the availability of transportation resources, the state of operations (e.g., can helicopters fly in and out at will for medical evacuation?), and medical's preferred strategy for support.

Exploring configurations

To develop information and communication requirements, we need to have a concept of what potential future medical structures will look like. Rather than trying to address the entire set of possibilities at once, we have chosen a sample set of configurations that cover as much of the continuum space as possible. We looked at how medical might be configured for three operational settings:

- Limited operations,
- Transitional operations,
- Sustained operations.

These three sample operations span the range of possible future situations that the Navy/Marine Corps team will face, and they will enable us to explore how medical configurations, and ultimately medical information and communication requirements, will vary across these operational situations.

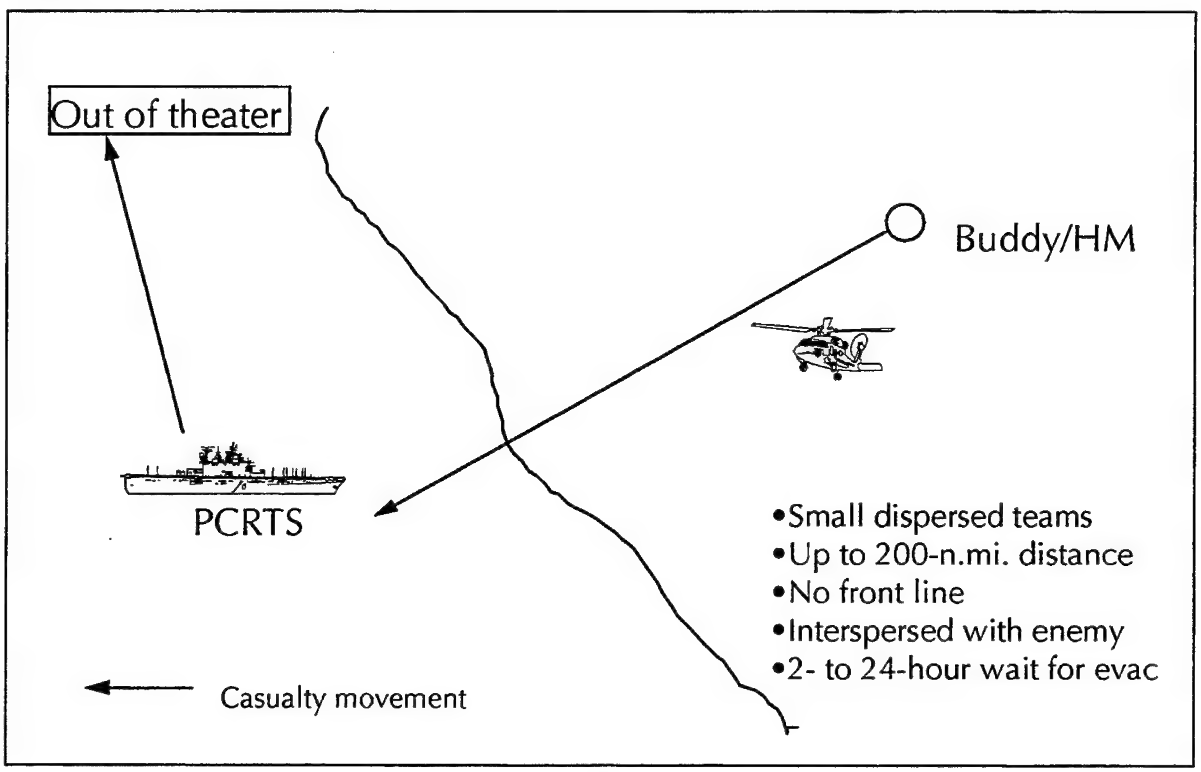
Limited scenario

The constraint in the limited scenario is that there be no support footprint ashore. Small, highly dispersed infantry teams will be operating as many as 200 n.mi. from their amphibious ship base (and, therefore, their combat service support). In addition, the teams are functioning in unsecured territory, interspersed with the enemy. It may be impossible to fly helicopters in for medical evacuation until the cover of darkness, or even until mission extraction.

Because of the distance inland, ground and surface medevac will be impossible.

We assume that a notional MEU would be a probable force configuration in the limited scenario, with three infantry companies operating ashore. The companies will function in four-man teams (approximately 129 teams). Medical support for this operation will consist of one corpsman for every three teams. The corpsman will function as a team member with primary medical responsibility. Infantrymen will also be expected to provide medical care. We assume augmented medical training for at least one Marine on each team. The team corpsman and medical infantrymen will be supported by medical personnel aboard a PCRTS (an LHA, or LHD). In this limited setting, the PCRTS will be expected to provide an expanded medical support (not the traditional echelon II care). No other medical support will be available in theatre (see figure 4).

Figure 4. Limited operations



Casualties will preferably be evacuated to the PCRTS as soon as operationally possible. But, this may not occur for as many as 2 to 24 hours. Therefore, the corpsman or buddy may be required to sustain a casualty for an extended period of time. Because of the high degree of mobility required for the teams, medical equipment and supplies will be kept to a minimum (each team member will probably be required to carry some medical supplies). In some cases, teams may have organic transportation, allowing some minimal additional medical equipment and supplies.

Transitional scenario

In the transitional scenario, a limited support footprint is permitted ashore. The basic operational infantry unit in this scenario is a 21-Marine platoon. While the battlefield is more defined under this scenario (there are pockets of secure territory), there will still be dispersion among the platoons, vast distances to be covered, and no clearly defined front line or rear. Casualties could expect to wait 1 to 12 hours for evacuation.

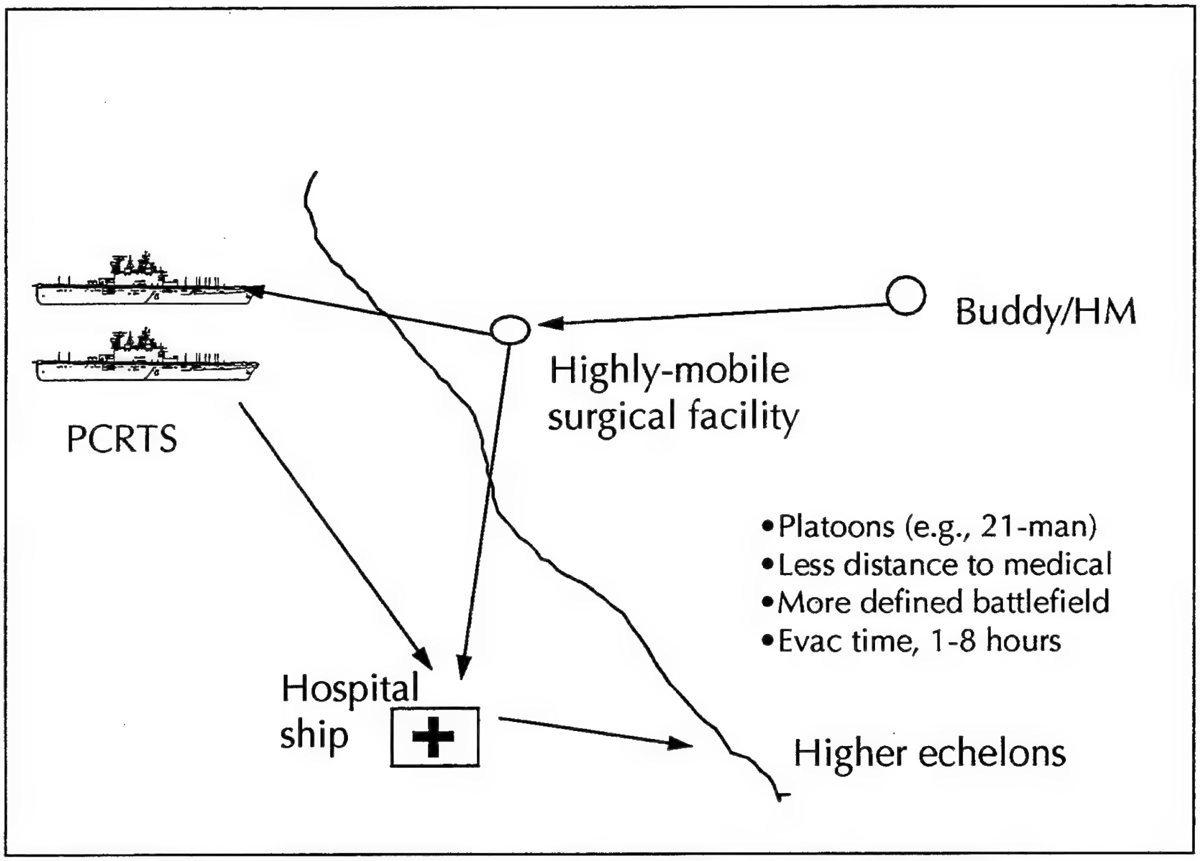
We assume that a notional MEF (FWD) would be a likely force size in the transitional scenario. Platoons will have corpsmen, and two or more Marines per platoon will receive augmented medical training.[24] There will be no battalion aid station. Some additional ground medical support will be provided by a Highly Mobile Surgical Unit (HMSU). This unit will be very mobile and surgically capable, perhaps some very light configuration of an STP augmented by a surgical element.[25] This unit might be a team of Marines dropped into a site with surgical/anesthesia equipment on their backs, although it might

24. We envision a program similar to the Army's Combat Lifesaver program. One soldier per unit is trained in advanced first aid, with an emphasis on hemorrhage control. The soldier functions first as a shooter, and second as a medical asset to the unit.

25. So far, the STPs can perform minor surgical procedures only. Their main mission to date is to support and augment the BAS, and deliver casualties to the surgical companies. At this point, they are predominantly an Advanced Trauma Life Support (ATLS) intensive unit, not a surgical asset.

also have some ability to transport and sustain itself. In addition to the HMSU, the corpsmen will be supported by medical personnel aboard PCRTSs (LHAs and/or LHDs) and, depending on the particular scenario, a hospital ship.[26] No other medical support will be available in theater (see figure 5).

Figure 5. Transitional operations



Casualties will preferably be evacuated to the ships for definitive care as soon as operationally possible. Otherwise, all attempts will be made to transport a casualty to an HMSU or vice versa. There may be cases were HMSU support or medevac cannot be achieved for several

26. As in the limited scenario, we assume that the PCRTSs will provide definitive surgical care similar to today's echelon III.

hours, requiring the corpsman or buddy to treat and sustain the casualty. As in the limited scenario, equipment and supplies will still be severely limited.

Sustained scenario

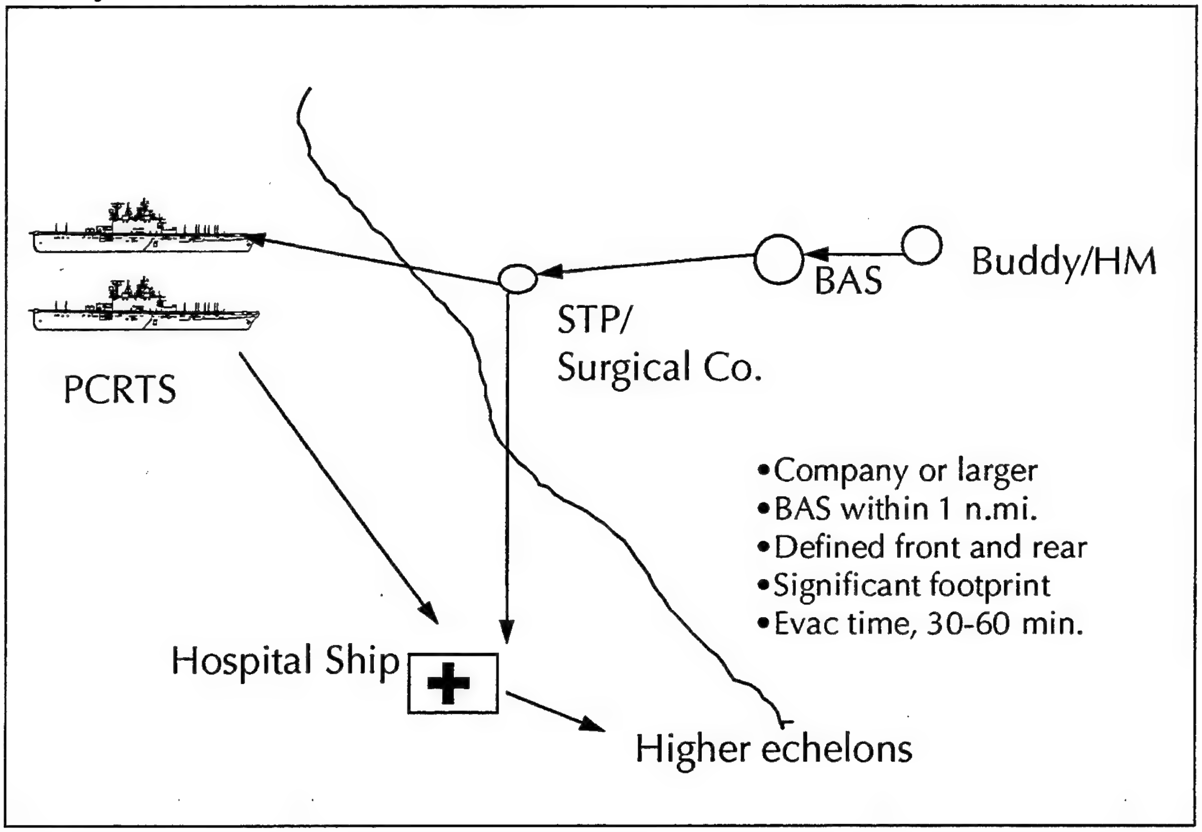
Finally, the sustained scenario will allow for a significant support footprint ashore (see figure 6). This will include the unit corpsmen, BAS, STPs, surgical companies, and fleet hospitals. Surgical companies might need to split into two at times. If they do split, they must be connected by communications. There will be a secure rear area, allowing for easier and more timely medevac, although availability of evacuation assets may still be operationally limited. Because so much ground support is available, we assume that the medical strategy is to treat the casualty as far forward as his injury warrants. This maximizes the likelihood of returning the Marine to duty. Additional support will be provided by PCRTSs, and possibly the hospital ship.[27]

In this case, the unit corpsmen will have a BAS within about 1 mile, and medevac times could be as short as 30 to 60 minutes. In turn, BASs will be supported and augmented by the STPs.[28] Ready evacuation and significant ground medical support implies that each site of medical care will be less responsible for sustainment of casualties than in the other two scenarios.

27. Depending on the scenario, it may be more likely that the hospital ship would be used in situations where little or no ground support is operationally feasible. In such a case, the hospital ship would provide necessary beds to support the force. In a sustained case with ground and air dominance, the need for bed space provided by the hospital ship may not be as important.

28. Although the table of equipment has not been finalized for the STPs, they have been described as ATLS intensive. Therefore, we assume the STPs will provide additional capabilities to the BAS.

Figure 6. Current sustained operations



A range of medical strategies

We have provided examples of medical configurations that might be used to support the forces in each of the three general scenarios. There are a range of medical strategies that may be pursued in each scenario. We have presented some of the considerations determining the availability and readiness of medevacs. In addition, medical can be dynamically transformed along the "care-to-patient/patient-to-care" continuum by (a) altering the level of training for medical personnel and infantry in each scenario, (b) developing and providing new technologies for medical equipment, medicines, and other medical supplies—enhancing the ability to perform more advanced procedures and diagnoses in the field, and (c) bringing medical expertise closer to the site of injury through communication and information technologies.

Chapter 4: Determining future medical information requirements in the field

This chapter presents future medical information requirements in the field, from the point of initial wounding, up to but not including the PCRTS. We describe our *methodology* for determining information requirements, and we detail our *findings* on future information requirements. Then, we answer three questions about information requirements:

- What decisions can be improved by consultation, rather than plain information?
- In what direction should information flow?
- What type and form of information is required (training, data, voice, image, or video)?

Method

Information is useful when it is the right kind of knowledge, provided at the right time, to the right people, in the right form.[29] As we said in chapter 1, there are two major kinds of information:

- Immediate knowledge of a particular event or situation
- Knowledge derived from study or instruction before a crisis occurs.

In this chapter, we investigate the relative merits of immediate versus training knowledge for medical.

29. This means that raw data should not be sent indiscriminately. Information needs to be organized and formatted to be fully useful [13].

Information can reduce uncertainty in making decisions and, if used properly, improves decision quality. The need for particular information is driven by three factors, which we call "requirements drivers." By analyzing these drivers, we determine medical's information requirements. Those drivers are:

1. The general *functions* of battlefield medicine, and the general *decisions* required to perform those roles: What do I have to do?

2. The *resources* that medical can use to perform its functions, including time, equipment, and personnel: What resources—general and specific—can I use to do it?

3. The casualty *conditions,* or opportunities for intervention, that medical must manage, and the prevention, treatment, and sustainment measures used to control them: What particular medical challenges do I face?

First, the *functions and decisions* of Navy medicine largely determine information needs. Second, *resources,* such as time and personnel, further constrain the type and usefulness of information. Third, *casualty conditions* greatly limit the need for information: only knowledge relevant to casualties' injuries is required. Information must be organized to support the needs of specific decisions. Without information, decisions lack a necessary foundation.

All of these drivers, taken together, determine information requirements. After we identify these drivers, we translate them into information requirements by specifying each requirement's type (immediate or training?), content (what needs to be known?), and form (data, voice, still image, or video?). A further outcome of the requirements specification process is to identify decisions that are most likely to require not just information, but consultation between two or more medical providers.

In this chapter, our analysis of information requirements includes seven major *functions* of medical, and the *decisions* within those functions. Our analyses of *resources* and *conditions* focus on the core medical functions of assessment and treatment, and deemphasize the other five medical functions (prevention, location, clearing, evacuation, and supply). We focus on assessment and treatment because

those are the areas where resources and conditions most determine medical's information requirements.[30]

Focus groups and interviews

We gathered data on requirements drivers and information requirements by conducting focus groups and interviews with fleet medical personnel on both the west coast and the east coast. We supplemented these interviews with followup phone calls, and with interviews with Army medical specialists and civilian paramedics who had experience with the use of communications aboard nonmilitary ambulances.

Focus groups are particularly valuable for addressing the functions and decisions of medical. Focus groups can be useful when the detailed research questions are still being developed, and when the questions are so far in the future that few numerical data are directly relevant [16,17]. These types of groups are good at helping to define the broad outlines of problems, getting a sense of the challenges people might face in unusual or unprecedented environments, and getting people's first reactions to questions that have never before been asked. Focus groups contribute to the basic understanding of how people think about an issue, what the important issues are, and what research questions are worthy of further study. They are very useful to develop a more complete understanding of people's duties, roles, and communications in complex environments. Focus groups should include a full sample of the relevant parties because they must collect impressions from all groups that have a stake in answers to the questions being addressed [17].

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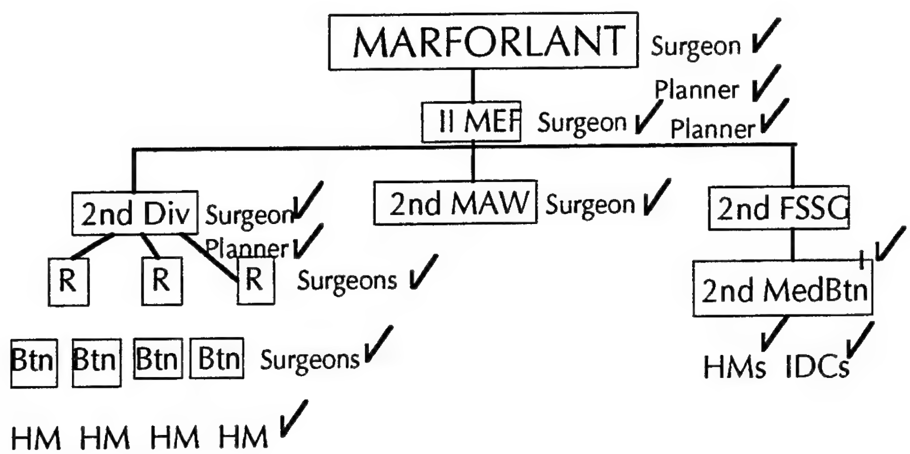
30. In contrast to assessment and treatment, resources for the other five functions (prevention, location, clearing, evacuating, and medical supply) come from both the warfighters and medical. For example, most of the transportation for locating, clearing, evacuating, and resupply comes from warfighters. Furthermore, as we will show, the resource of time is very critical to assessment and treatment. Lastly, decisions pertaining to assessment and treatment (and to a lesser extent, prevention) are most directly affected by casualty conditions. Decisions pertaining to location, clearing, evacuating, and resupply are less often affected by knowledge of casualty conditions.

Our focus groups were run over several days on both the east and west coasts. We began each focus group by asking the participants a set of questions on present and future medical support requirements (the questions are shown in appendix C). However, the focus groups were run in such a way that participants could bring up their own viewpoints or concerns. It was important that we sample from people who play different roles in the medical system. Figure 7 lists the commands and individuals we consulted on the east coast. We also interviewed those with corresponding roles on the west coast. This list shows a wide range of participants, from unit corpsman to force surgeon.

Figure 7. Focus group participants, east coast



We used these focus groups with Navy medical providers at Camp Pendleton and Camp Lejeune to:

- Gather data on the kinds of information and consultation that Navy medical personnel think would help support ground operations
- Understand better the kinds of information and equipment available to Navy medical personnel

- Appreciate the types of decisions that medical personnel must make in operational environments
- Analyze the kinds of injuries and illnesses that are most challenging for medical personnel to treat in operational environments
- Describe the nature of today's medical configurations to support a variety of operation
- Understand information and communication systems currently in use, including their strengths and weaknesses.

Medical exercise play

To augment the data we gathered from our focus groups, we also used analyses from CNA's participation in the medical portion of Kernel Blitz 95, called CG1. These analyses broadened our understanding of the challenges that medical faces in treatment, evacuation, and medical resupply. Those analyses included numerical data that CNA collected on the time between initial wounding and arrival at medical treatment facilities. The CNA effort included analyses of logbooks of, observations of, and interviews with personnel who worked on the medical regulating net, who treated casualties, or who worked on the coordination of medical supply efforts.[31]

Historical casualty data

To determine how much time decision-makers had to administer life saving care, as well as the types of injuries they face, we used the Wound Data and Munitions Effectiveness Team (WDMET) study data.[32] The WDMET study used detailed descriptions of about 8,000 U.S. Army and U.S. Marine casualties wounded in an 18-month period between 1967

31. Those analyses for Kernel Blitz were used to reconstruct the performance of the treatment, regulating, and medical resupply systems in a traditional amphibious operation [18].

32. These data are analyzed by Colonel Ronald Bellamy in a recent edition of the *Textbook of Military Medicine* [19]. The WDMET data are proprietary and in paper form, so we could not analyze these data ourselves. As a result, we relied on Bellamy's writings and interviews for the analyses reported here.

and 1969 during the Vietnam war. Teams of research assistants accompanied company- and battalion-sized units during tactical ground operations. The WDMET team collected data on the tactical situation, the weapons that caused the wounds, field first aid, and the detailed anatomy of wounds (including autopsy reports for those who died), and initial medical care in military hospitals.[33]

Simulated casualty flow and treatment data

In addition to the above sources, we turned to additional data to analyze the impact of resources and patient conditions on information and communication requirements.

The Time Task Treater Files of the Deployable Medical Systems (DEPMEDS) provide data on 339 casualty conditions [20], including the probability distribution of conditions associated with an estimated casualty stream, and the tasks and time associated with treating each condition.[34] This data set focuses on echelon III and above. Currently, the Directorate of Combat Doctrine Development at the U.S. Army Medical Department and School (AMEDD) is developing a

33. The WDMET study is unique because it tried to describe *all* casualties during a particular combat action—the killed-in-action and those who were never sent to a higher echelon of care, in addition to those casualties who were sent to hospitals. Bellamy reports extensive data on the physiological distribution of injuries, length of survival, treatments, and outcome of treatments. We used these data to determine *the length of time that casualties survive* before getting medical care. These estimates assume that weapons and injuries from the Vietnam conflict are similar enough to those that Marines will face in the future. To our knowledge, WDMET is the only data set that can address historical length of survival for such an extensive number of U.S. casualties.

34. DEPMEDS is overseen by the Defense Medical Standardization Board. It was developed with the cooperation of 21 panels of expert clinicians, and reviewed by the Joint Services Clinical Review Group, composed of senior physicians representing each of the services. The Academy of Health Sciences organized the data into a form that could be used for various purposes. As a result, the DEPMEDS data are the most useful available for determining the conditions, treatments, and supplies used for a list of all common medical conditions expected in an operational environment.

parallel database for echelons I and II. Because the focus of our study is at the field level, we relied primarily on the AMEDD data.[35]

These data from AMEDD allowed us to identify those tasks performed at the site of injury, the battalion aid station and the surgical company; the primary performer of each task; and the probability that a casualty with a specific condition requires each task. Based on our analysis of the focus groups and interviews with clinical experts, we were then able to establish which of these tasks would require, or benefit from, information and communication exchange. Combining this with AMEDD's estimated Marine casualty flow for a worst-case scenario MRC, we were able to estimate the frequency and duration of calls associated with these requirements.[36]

Findings

Driver 1: Functions and decisions of battlefield medicine

Functions

In general terms, the wartime mission of Navy medicine is to support the Navy and Marine Corps during operations. A number of publications have outlined how to accomplish this mission, most notably FMFM 4-50, *Health Service Support* [11], and NWP 4-02, *Operational Health Service Support* [22]. These and other publications are being updated by the Marine Corps Combat Development Command (MCCDC) and the Health Service Support Detachment of the Naval Doctrine Center. Further work, such as that being done by the Naval Expeditionary Concept of Casualty Care (NEC^3) workshop, to

35. The AMEDD echelon I and II database will ultimately be merged with DEPMEDS; therefore, the coding, definitions, and makeup of the AMEDD data are very dependent on DEPMEDS.

36. The AMEDD casualty flow for a worst-case scenario supported our analysis of the sustained configuration scenario. For the limited and transitional configurations, we were able to combine the AMEDD echelon I and II data with CASEST estimates generated specifically for our use. The CASEST (casualty estimation) computer model is the official Marine Corps tool for predicting troop replacement needs [21].

determine a new concept of care for the future could certainly redefine what some of the decisions will need to be and, by implication, who will need to make them. Using current doctrine, we stipulate that, in a ground conflict, medical Navy personnel have major roles in:

- Preventing casualties
- Locating casualties
- Clearing and protecting casualties
- Assessing, diagnosing, and triaging casualties
- Treating and sustaining casualties[37]
- Evacuating, regulating, and tracking casualties
- Providing medical supply.

The ability of medical to perform each of these functions will be affected by such future concepts as OMFTS and Sea Dragon. This is especially true for the limited and transitional scenarios. For example, the lack of a support footprint, interspersion with the enemy, and general uncertainty that accompanies these types of operations will affect medical's ability to prevent disease and nonbattle injuries and to locate, clear, and protect casualties. Sea-basing of logistics and the need to supply several small, highly dispersed units also pose large challenges for the logistic community as a whole, including medical.

With limited ground medical support (no BAS, no surgical company), casualties will need to be evacuated directly to a PCRTS. These ships could be as far as 200 n.mi. from the injured Marine. In addition to these large distances, air evacuation may not be possible until cover of darkness or even mission completion. This means that casualties will need to be treated initially and sustained longer by a more limited medical crew—unit corpsman, HMSU, or in some cases another Marine—with limited equipment and supplies.

37. This includes trauma care, disease and nonbattle casualties, prescreening, routine sick call, monitoring infectious and noninfectious disease, as well as surgical and nonsurgical trauma care.

Specifying these medical functions and understanding how they fit into future operational concepts is the first step in developing information requirements.

Decisions implied by functions

The functions of Navy medicine just specified allow us to list some of the many decisions that must be supported by information. Once we list some decisions, it is easier to specify the content and form of information needed to support medical's functions.

Preventing casualties. Preventing casualties is a line function, but the warfighters depend on Navy medicine for the technical knowledge and decision-making to assist them in that function. Decisions under preventing casualties might include:

- Will there be varieties of environmental conditions, such as heat, cold, and wind? If so, what preventive actions can we take?
- Is there a possibility of chemical, radiological, or biological warfare? If so, what preventive measures can we take?
- What precautions should be taken with local water, food, cooking, sanitation, and local animals and plants?

These kinds of decisions require a lot of information particular to the region.[38]

Locating casualties. The corpsman who will make first contact with a casualty, the transportation driver, or even the mobile shock trauma platoon must deal with locating casualties. Clearly, information can improve these decisions, such as:

- How many casualties are there?

38. While much of the information needed to support medical's role in prevention will be provided by the line community (via intelligence), medical can contribute to prevention by reporting all disease incidents in a timely and organized manner. This would allow medical intelligence to track infectious disease, environmental hazards, and biological threats, giving the line the opportunity to stop the spread of such hazards among the troops. Another role of medical is to ask the right questions in determining the medical information that should be kept.

- Where is the casualty, and what is the best path to take there?
- Could someone else reach the casualty more quickly than I can?
- If I am closest, are there dangers to avoid in reaching the casualty?

These decisions require information from the warfighter to improve situational awareness.

Clearing and protecting casualties. Clearing and protecting casualties also demands decisions of the corpsman or other personnel responsible for casualty handling. Information can support the speed and accuracy of these decisions. Examples of these decisions include:

- What is the nature of the casualty?
- What equipment, personnel, and supplies should I bring to the casualty?
- Is the casualty a threat?
- Should I clear the casualty immediately, or treat him first?

These decisions require situational awareness and awareness of the casualty's condition. Again, specifying these decisions starts to identify the information that would be most helpful.

Assessment, diagnosis, and triage of casualties. Medical personnel will need to make decisions about assessment and triage. Examples of decisions might include:

- Are there other casualties I will need to take care of soon?
- Is this casualty alive or dead? Can he be resuscitated?[39]
- Does the casualty need immediate life-saving intervention? (Primary survey[40])

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39. Data supplied by sensors or analyzers might help with these kinds of decisions.

40. We use *survey* here to mean the assessment of the casualty's condition. This use of the term *survey* is from the *Advanced Trauma Life Support Course* [23].

a. Airway maintenance and cervical spine? What procedure?

b. Breathing and ventilation? If so, what procedure?

c. Circulation and hemorrhage control? If so, what procedure?

d. Does the casualty need to be protected from the elements?

These decisions require information about the group of casualties as a whole, as well as detailed information about the casualty that is currently being assessed. Many of these decisions require background information that comes from training.

Treating and sustaining casualties. All personnel who handle casualties might need to make decisions about how to treat them. Information is required to make these decisions. Here are some examples of the kind of decisions that must be made:

- Should I give this casualty more pain medication? If so, how much?
- Should I give this casualty more antibiotics? If so, how much?
- Should I remove this casualty's limb? Should I change the tourniquet?

Both observation and training information are needed to make these kinds of treatment decisions. In addition, any subsequent treatment of a casualty requires that the treater know what prior treatment was performed.

Evacuation, regulation, and tracking of casualties. These functions require a great many decisions about priorities, use of resources, and timing. Examples of these decisions include the following:

- Where should I send this casualty?
- Should I reroute a particular set of casualties?
- What MTFs are available to handle this casualty?

Information about the entire set of casualties and the capabilities of the MTFs is essential to make these kinds of decisions.

Medical supply. Medical personnel also make decisions that would be aided by having information about medical supply. Examples of those decisions include the following:

- Am I in danger of running out of supplies?
- Should I reorder even though I ordered a few days ago?
- How critical is the need for this medical supply?

Clearly, detailed information about the supply system, what has been ordered, where the order is in process, and expected delivery date would help with these kinds of decisions.

Driver 2: Resources

In this section, we will focus mostly on *assessment* and *treatment* functions because (a) medical owns most of the resources for those two functions and (b) assessment and treatment are the most resource-intensive of medical's functions. There are three major resources for medical, all of which can determine what form and type of information is required:

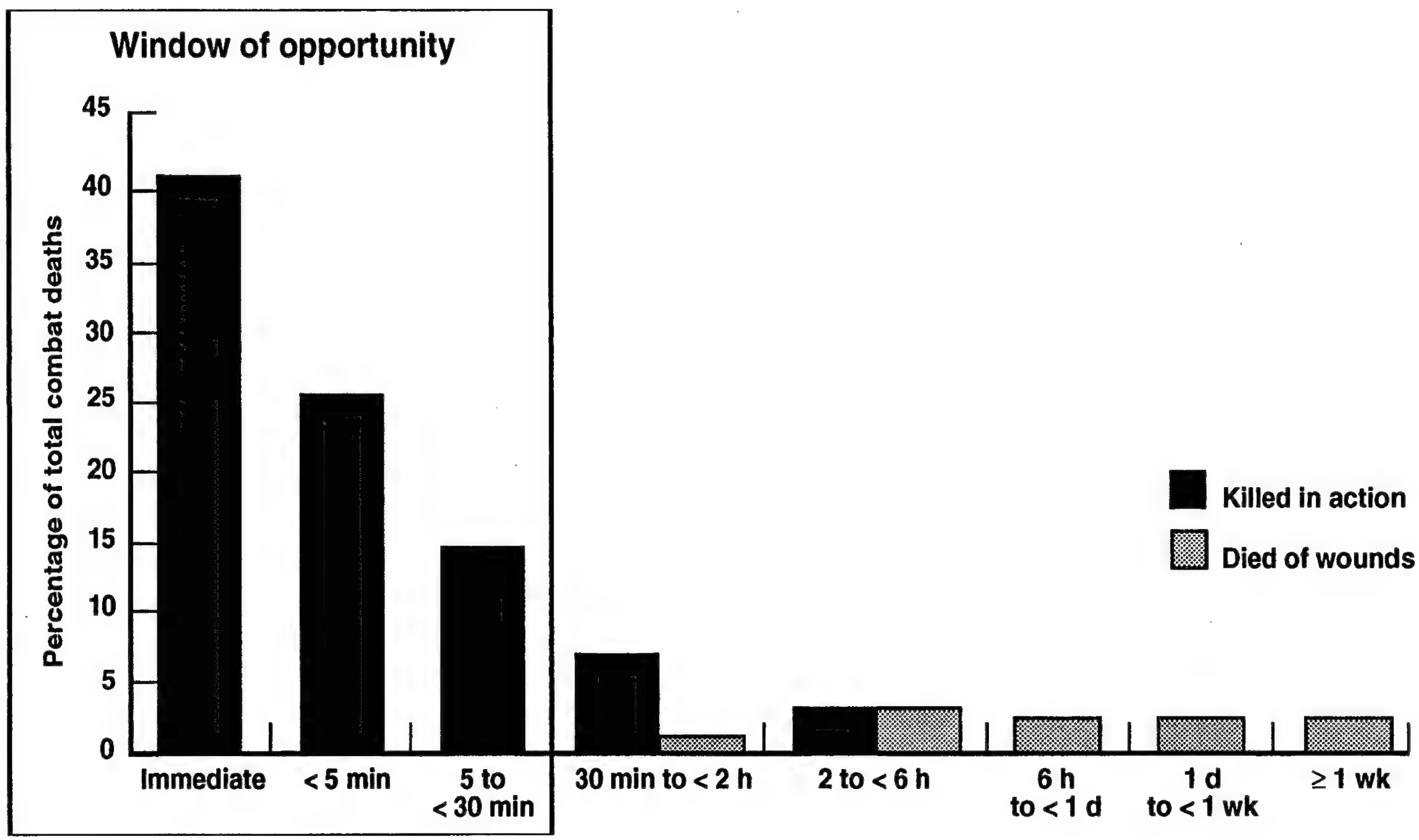
- Time
- Personnel
- Equipment/supplies.

We will analyze how each of these resources affects information requirements, in turn, primarily as they affect assessment and treatment functions of medical.

Time

By far the most important resource driving information requirements is time. In large part, time determines other resources: what personnel are available, what equipment is needed, and what other resources would most assist medical. Data on time from initial injury to death specifies how much time personnel have to make certain decisions. As you can see from figure 8, based on Vietnam data [19], over 40 percent of battlefield deaths are immediate, and another 25 percent die within 5 minutes of injury. The next largest groups die within 5 to 30 minutes or in less than 2 hours. These statistics tell us

Figure 8. Time from injury to death, Vietnam[a]



a. Source: [19].

that information to help save lives must be available and acted upon within minutes of a trauma casualty's injury.

Time to death presents a major limiting factor to the need for speedy evacuation: if the casualty is so far away from a PCRTS that he cannot be taken there within 30 minutes, the initial emphasis should be on quick, quality treatment in the field, rather than quick evacuation. You are better off training unit corpsmen or infantrymen to make fast, accurate treatment decisions and giving them good, lightweight medical equipment with which to act on those decisions.

Although lack of time is a major limiting factor, time is also an important consideration when the corpsman or buddy must hold the casualty for long periods. Under the new operational concepts, with the greater distances from medical facilities and difficulties in providing medevac to small, highly dispersed units, corpsmen or even buddies may have to treat and sustain a casualty for up to 8 hours in the transitional scenario and up to 24 hours in the limited. This time has implications for the kind of information needed: in addition to firstaid information, information about sustainment will also be quite important.[41]

Personnel

Time determines what personnel are able to save a casualty. These time limits mean that the buddy and corpsman are the two most critical individuals from the standpoint of saving lives. To the extent that information can provide better or faster assessment and treatment within 30 minutes or less, it is possible to make a large impact on battlefield fatalities.[42]

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41. This situation will be discussed in the upcoming section on decisions that require consultation.

42. These statistics show that information supplied to higher echelon MTFs—such as PCRTSs, hospital ship, and fleet hospital—cannot make as large a difference in mortality of battle casualties. Information and communications will still be useful at those levels, but the primary metric of improvement should not be lives saved. It might be better measured by the quality of life after injury, speed of recovery, reduction in staff specialists, cost savings, or other metrics, such as the operational effectiveness of the ship by having prevented illness or medevac.

In summary, the data on time shows which personnel are available to make most life-saving interventions. They are:

- The casualty himself
- Search and rescue teams
- The casualty's buddy
- The field corpsman
- The Battalion Aid Station (BAS).

Which *type* of personnel can make the right decisions in the small amount of time available for emergency treatments? Well-trained ones can. Training makes the available personnel more capable. It can be applied instantaneously, weighs nothing, and uses up no space in one's knapsack. *Training is the most important type of information for life-saving interventions.* The more training, the faster you can provide quality care. Conversely, poorly trained personnel take too long to make decisions, and those decisions are often wrong. Training counteracts the negative effects of lack of time for assessment and treatment, and it can improve the utility of immediate information sources that must be applied quickly under great stress.

Equipment and supplies

Limited equipment and supplies in the field affect the usefulness of certain types of information. Because corpsmen have to keep up with their units, they have very limited space in their unit 1 bags. Even if corpsmen have unit members carry small amounts of medical supplies, corpsmen cannot do procedures that require specialized surgical tools, or more than the most basic of medications or heavy medical appliances. No matter how much training you get, *equipment and supplies limit what can be done in the field.* Corpsmen do not always have the most modern, most lightweight equipment to do advanced trauma life support (ATLS). Situations at the BAS and STP are also quite limited, although less so than for corpsmen.

Our findings regarding equipment have one major implication: Information is needed *only* for procedures for which corpsmen have both the time and the specialized equipment that they need.[43] Information regarding complicated medical procedures requiring specialized equipment is not needed at the site of injury, the BAS, or the STP.[44]

Driver 3: Casualty conditions, prevention, and treatment

The previous section summarized how resources drive the need for information, especially for the functions of casualty assessment and treatment. In this section, we analyze how casualty conditions affect the need for medical information. Again, we focus mostly on casualty assessment and treatment decisions.

Conditions

The clinical conditions of troops also will drive information requirements. For this we will use the WDMET data. Figure 9 shows some of the most common reasons for death in Vietnam. Exsanguination caused 44 percent of all deaths occurring in the battlefield (killed in action) and was the single largest killer. This shows that controlling bleeding is critical to reducing deaths in the field. This capability is fairly easy to train; in fact, the ability to reduce bleeding has been the major goal of the Army's Combat Lifesaver program, which trains one infantryman on each small squad to be proficient at hemorrhage control by manual or tourniquet pressure. Having better training for infantrymen or a similar combat lifesaver program for Marines could make a fairly significant reduction in battlefield mortality.

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43. It also suggests that, at present, investment in developing certain equipment and supplies could have a very high payoff. Three examples would be: (1) a lightweight, easy-to-erect, tactically adequate (allows no light to escape at night) STP shelter; (2) lighter, easier-to-use field AMALs; and (3) better emergency life support equipment.

44. As noted before, the STP is still being defined in terms of its Table of Equipment (TOE). Its need for specialized information may increase depending on its final responsibilities.

Figure 9. Cause of death, Vietnam[a]

88% killed in action (before reaching the BAS):
Exsanguination from extremity (10%)[b]
Exsanguination from main body (34%)
Central nervous system, head wound (31%)
Multiple wounds (13%)
12% died of wounds (entered into the medical system, BAS or higher):
Central nervous system, head wound (5%)
Multiple organ failure, infection (4%)
Shock (3%)

a. Source: [19].

b. Bold type reflects opportunities for lifesaving intervention at the site of injury, given current and expected medical treatment technologies.

Another implication of the findings in figure 9 is that training in administration of antibiotics and blood or other fluids might be helpful[45] because multiple organ failure (MOF, 4 percent) and shock (3 percent) are also large causes of death. Unfortunately, it is not possible to use training to avoid death due to wounds to the head (CNS), constituting 31 percent of killed in action. Avoiding deaths from head wounds would require radically new medical technologies and training.[46]

45. Currently there is controversy concerning whether immediate administration of fluids is beneficial or detrimental to casualties. This is an issue that we leave to the medical community to resolve.

46. A significant effect on mortality rates due to head injuries would require a major medical breakthrough, such as "suspended animation." This type of breakthrough would probably require special training and increased teleconsultation to identify candidates for such treatment and to help maintain casualties' stabilized status. The statistic on head wounds also demonstrates the importance of preventing them in the first place, perhaps with better helmets or other technologies.

Historically, some of the most common *casualty conditions* involve infectious disease or nonbattle injuries [19]. Those findings indicate that, regardless of the combat situation, medical must always have the training and resources needed to deal with infectious diseases and nonbattle traumas. Medicines, skills in internal medicine, and knowledge of orthopedic conditions will always be needed.

Prevention and treatment of conditions

To ascertain the measures medical must take to prevent or treat particular casualty conditions, we used focus groups, interviews with clinical experts, and the AMEDD data on field tasks at the site of injury, BAS, and surgical company. For example, we found that the following information would be useful:

- What, if any, drug allergies does this casualty have?
- When was the tourniquet applied?
- What drugs were administered, and when?
- How did the injury or illness occur?

Some of these information needs that arise from casualty conditions concern patient movement. For example, personnel who are transporting casualties might need to know when a tourniquet was applied and whether they should change the tourniquet in route. Transport personnel also need to know if they are going to transport a chemical or biological casualty.

Decisions that can be improved with consultation

So far we have talked about the three requirements drivers, namely, (1) medical functions, (2) medical resources, and (3) casualty conditions. We have focused primarily on decisions that need *specific* information, such as location and details about a casualty's injuries. And we primarily focused on assessment and treatment decisions.

But some decisions may require more than specific information; they need *consultation* with an experienced and knowledgeable person. These decisions require "judgment calls," or expert procedural knowledge, and cannot be decided on the basis of a simple set of rules

or guidelines. The findings from the focus groups about these consultation requirements were that, in fact, *assessment and treatment* decisions were the only choices in which consultation would often be needed:[47] *data* would ordinarily be sufficient for decisions regarding regulating, supply, locating, protecting, and clearing casualties.

Our findings show that consultation is required in the limited and transitional scenarios, in which medical personnel might need to hold casualties for many hours longer than has been the case in such conflicts as Vietnam. In the sustained scenario, consultation may be required at the surgical company to compensate for the absence of specialists since the reorganization of the medical battalion. For the corpsman, examples of the treatment decisions that might require consultation were as follows:

- *Conditions requiring a surgical procedure that could do harm if performed unnecessarily or incorrectly.* A cardiac tampanade is an example.
- *Multiple injuries,* because of their complexity, are conditions that corpsmen might most want to consult about with a physician. How do I treat burn and penetrating missile wounds in the same individual?
- *Administration of drugs and fluids,* especially because in the limited and transitional configurations corpsmen will have to care for a casualty for a longer period than has been the norm.
- *When assessment of the casualty is particularly complicated.* For example: Do I need to remove this limb? Is this casualty well enough to return to duty?

47. Although we talk about voice consultations in this section, e-mail could support some of the less urgent consultations. Furthermore, an expert system, in the hands of the corpsman, might reduce the need for some consultations. In this section, we assume that e-mail will meet some of the need for consultation. We also assume that there is not yet a handheld expert system of sufficient quality and ruggedness that it can replace the need for e-mail or voice consults.

- *Disease diagnosis.* Consultation might be required when diseases are unusual, hard to diagnose, or never seen before: Is this malaria, pneumonia, or a case of the flu?
- *Long-term sustainment.* The corpsman would need consultation when the length of time a casualty must be sustained requires more information (e.g., when a casualty stays with a corpsman so long that the corpsman must do a procedure ordinarily done by a physician).

Especially in the limited configuration, having voice communication might be important because, as shown in our description of the future battlefield, casualties might have to wait quite long periods before evacuation is possible. Therefore, voice communication with physicians and physician assistants aboard a PCRTS could be quite valuable. It could also be important because voice communication could help decide whether the casualty's condition is such that evacuation is the only way to save a life. In the limited configuration, you want to have *necessary* medevacs only because of the danger involved.

In the transitional configuration, it will also be important to have voice communication for treatment consultations because you do not want to overwhelm the highly mobile surgical units with unnecessary cases. The largest role of voice communication is to maximize the ability of medical providers to treat and sustain the casualty while waiting long periods for medevac. The highly mobile surgical units should be taking only those casualties that truly need surgery immediately. Otherwise, casualties should be overflying the surgical units to go straight to the PCRTSs.

Consultations are also likely to be needed from the surgical company, where a general surgeon might want to consult a specialist when performing major surgeries for life and limb salvage. For example, a good number of "major" procedures performed at the surgical company are limb salvages, which consist mainly of repairing major vascular and bone injuries. Once this repair is accomplished, the bone must be stabilized. Typically this is done by an orthopedic specialist, but these specialists are no longer at the surgical companies. Shipping a casualty with an unstable fracture may undo the vascular repair (threatening life and limb). In this case, the general surgeon at the

surgical company could consult with an orthopedic specialist to receive advice/instruction on stabilizing the fracture before moving the patient to the next level of care.

Direction of information flow

We found that a central feature of a consultation system is that communications should be initiated only by the person closer to the site of initial injury, pulling information. Corpsmen and physicians repeatedly stated that they did not want unsolicited advice about how to treat patients. They would like to have the backup capability to ask for help when they deemed it necessary; but it would cause severe morale problems if higher echelon personnel were "looking over their shoulder" and second-guessing their decisions. Therefore, we conclude that consultations should be initiated by the provider who is currently treating a casualty; in other words, the provider should "pull" information.

What *type* and *form* of information is needed?

We have analyzed the three requirements drivers to determine the *content* of information needed. But what *type* and *form* should that information take—training, data, voice, image, or video? The question is important because there is significantly greater cost attached to still image and especially full-motion video, both monetary cost and in terms of bandwidth and data rate requirements.[48] In this section, we summarize our findings about the type and form of required information. These findings relied primarily on our focus groups.

The *regulating/tracking system requires mainly low-rate data transmission*, which has advantages of being inexpensive and able to keep an electronic bulletin board that would improve situational awareness. Voice would be a backup information system for regulating/tracking. Similarly, for the *medical supply system*, the focus groups revealed that *data were preferred*, with voice as a backup system to verify entries, correct mistakes, or to be used if the data system goes down.

48. Chapter 6 details how large the cost differences are between forms of information, such as data, voice, and video.

We found that *training is the most important information source to support treatment.* In addition to training, the treatment system needed *voice communication to support teleconsultation.* Treatment also required a *data system for reporting patient care and condition,*[49] *for situational awareness, for obtaining medical history, and for tracking diseases for prevention.* At the surgical company, we found that increased capabilities would be needed to allow general surgeons to consult with specialists. These include image and possibly video.

Training

Our analyses show that training is the critical information requirement necessary for treatment. Respondents said that relying on communications could slow them down, and that this would be a problem when dealing with time-sensitive emergency situations.[50] This is supported by the WDMET data on time to death and cause of death on the battlefront. Interviews with paramedics in the civilian sector about how they used communications in emergency situations indicated that the recent trends were toward (a) less need for paramedics to "get permission" to treat patients (to save time) and (b) more training for paramedics, so that they can handle a wider range of situations without physicians needing to intervene.

In the limited and transitional configurations, unit corpsmen and Marines will be expected to provide significantly more care than has previously been the case. This would require redefining the core responsibilities of these individuals, and training to these new requirements. Finally, training is essential to the successful integration of any other information system. Corpsmen and Marines must be able to assimilate this information and perform those functions that

49. A data system can include low-resolution graphics. Data, image, and video systems can include color. We deal with system requirements for color in chapter 6.

50. We heard about the slowing process informally from an Army respondent who had been in contact with participants in Advanced Warfighting Experiment (AWE) exercises that used medical communications [24, 25].

voice consultation would require (limited, of course, by the environment and equipment).[51]

Voice communications

We found that voice communications are preferable for consultations about how to diagnose or treat casualties. In contrast to data, voice communications allow medical personnel to pierce the "fog of war" and ask questions if the situation is confusing. Voice communications have the further advantages of having authority and, therefore, boosting a corpsman's self-confidence. Sometimes these communications would be a brief reassurance in decisions of major importance to the casualty (e.g., whether to amputate); in other cases, more extensive consultations might be needed (e.g., when a corpsman's initial treatment has not worked, and he wants a physician's suggestions).

In the preponderance of cases, at the site of injury (up to but not including the surgical company), video or still image would provide more information than necessary. This still image or video would come at a significant cost in terms of equipment, bandwidth, and, in some cases, confidence and autonomy of those ultimately responsible for treating the casualty. Our analyses show that in the majority of these cases, voice communications were sufficient to provide mentoring and consulting information.

Lastly, corpsmen and battalion surgeons told us that, at present, voice communications were not reliable: getting *reliable voice communications* would be a considerable improvement over the current situation.[52] E-mail and data could also improve matters for corpsmen and battalion surgeons.

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51. Physicians and corpsmen said that they don't want to talk a person through a procedure that he or she has neither performed nor been trained to do.

52. We also asked civilian paramedics about the use of image or video for consultation in ambulances when accompanying patients to emergency rooms. They said that the most they use is voice communications. Of course, it should be noted that, on average, civilian paramedics have a much shorter holding and transport time than would a military medic.

Data

We found that data are the best medium for exchanging information regarding identification, treatment history, evacuation requirement, regulating, supply requirements, as well as battlefield situational awareness for location and protection of casualties. Data could be viewed as the backbone of an "electronic bulletin board." Data are amenable to "store and forward" technology, meaning that the bandwidth and data rate requirements diminish considerably—and get less expensive.

Image and video

Based on our analysis of focus groups and data, we concluded that image and video data were *not* necessary or desirable at the point of injury, the BAS, or STP.[53] The respondents believed that any kind of camera further forward than a surgical company would (a) be a burden to carry, (b) be a burden to set up, (c) increase the corpsman's feelings of vulnerability, (d) decrease a corpman's morale, and (e) reap very little benefit because of the resource and environmental limitations these providers face in the field. However, still image and video technology could prove useful at the surgical company, especially because of the lack of specialists (e.g., orthopedic, cardiothoracic, or neurosurgeons) in the new medical battalion configuration.[54, 55]

53. There was overwhelming agreement among respondents that the surgical company was the first place where image and/or video might be useful. Those who liked the idea of image or video before the surgical company were in a decided minority.

54. Our conclusion that information in the form of image or video is not required close to the site of initial injury should not be taken as a criticism of telemedicine aboard ships or at the surgical company. Telemedicine aboard ships is very different because (1) there is a fairly secure environment, unlike the situation near the site of initial injury, (2) large antennae are already available on ships, and (3) the alternatives to shipboard telemedicine—medevac or changing a ship's deployment—are very expensive.

55. Although the surgical company has no surgical specialists in its table of organization, surgical specialists can be employed if needed.

Summary

In this chapter, we developed information requirements by analyzing the *functions and decisions* of Navy battlefield medical, the *resources* available, and the *casualty conditions* that must be prevented or treated.

We found that Navy battlefield medical *functions* to:

- Prevent casualties
- Locate casualties
- Clear and protect casualties
- Assess, diagnose, and triage casualties
- Treat and sustain casualties
- Evacuate, regulate, and track casualties
- Obtain medical supply.

Some of the most common *casualty conditions* involve infectious disease or nonbattle injuries; the most common battlefield trauma causes of death are:

- Exsanguination
- Injury to the head or central nervous system
- Injuries to multiple systems
- Multiple organ failure
- Shock.

Finally, we looked at how some of the limits on available time, personnel, training, and equipment work to constrain the utility of information to some caregivers in some situations. Specifically, we analyzed the minimal amount of time available, less than 30 minutes, to make life-saving interventions, and the limited equipment available to a unit corpsman because of space and environmental constraints. We bring all of these drivers—medical functions, casualty conditions, and limited resources—together to determine information requirements.

We conclude that:

- Training is the most useful type of information for life-saving emergency assessments and treatments.
- Low-end information technologies (data and voice) could make important contributions to medical's seven functions (listed on the previous page).
- Reliable data and voice communications are sufficient information carriers to support medical from the point of initial injury up to the point of initial surgical procedures (usually the surgical company).
- At the first point of fixed facilities (usually the surgical company) image or video communications might compensate for the lack of specialist physicians there.
- Information should be pulled as needed and as requested by the personnel treating the casualties. There should be no uninvited telemedicine presence.
- Lack of time, equipment, and supplies affect the usefulness of information by limiting what can be done in the field; therefore, information requirements need to be analyzed in conjunction with the resources that medical personnel have available.

The next chapter will translate, in layman's terms, what these findings mean for a minimal communication system that will carry the required information for Navy battlefield medicine in the year 2020.

Chapter 5: A nominal communication system

So far we have portrayed the *content* and *form* of information requirements. Here we describe, in nontechnical terms, what minimal communication systems might look like. In outlining these systems, we include who needs to talk to whom, and in what form. We discuss the proposed communication systems as if they are stand-alone medical nets; in practice, however, they might be joined with communication systems of the warfighters. We believe that three conceptually distinct systems (that might not be distinct, in practice) are needed:[56]

- Evacuation, regulating, and tracking
- Supply
- Treatment.[57]

We believe that data systems are needed as the primary communication method for two systems: (1) evacuation, regulating, and tracking and (2) supply. Data can produce several distinct types of products, including e-mail, low-resolution graphics, text, electronic bulletin boards, and numeric streams. Voice will be a backup for those data systems. Although training is the primary form of information needed for treatment, both voice and data will be necessary for a third system, treatment. In the following sections, we will detail each of these three systems. Then we will consider the practical operational characteristics needed for the nominal system that we describe.

56. Systems for location and protection are primarily being developed by the warfighter, and medical must be able to tap into the warfighter's battlefield picture. Prevention information would come via warfighters' intelligence systems and in medical's treatment communications.

57. For the purpose of setting up a communication system, we include assessment/diagnosis/triage functions within our treatment function.

Evacuation/regulation/tracking system

The basis for an evacuation/regulation/tracking system would be a low-rate data system in which all those who participate in this function will input relevant information into a "data cloud." The system would be used to create electronic bulletin boards to which many people would have access, creating a nearly real-time picture of the evacuation/regulation/tracking processes. Figure 10 represents this system in the sustained configuration,[58] from the site of injury up to, but not beyond, the PCRTS.

The figure shows those players who would input and extract information from the data cloud. For example, the unit commander, STP, and S-1 would both input and extract information (as indicated by arrowheads on both ends); in contrast, ATF command and JTF HQ would primarily extract information (as indicated by the single arrowheads). This information would be "smart pushed" to users and could also be "pulled" by the users. "Smart pushed" means that information will be automatically updated without intervention by users; "pulled" means that users actively request the data. The electronic bulletin boards for regulating, tracking, and medevac status are examples of products that would be created and maintained using information from the cloud.

Personnel at the treatment nodes (HM, BAS, etc.) and the regulating officer[59] are both taking from the system and inputting new information to the system. The figure shows that a great many nodes will take from the cloud, because information about casualties is of interest to many different people, from the casualty's buddies and unit commander, all the way up to members of the joint task force (JTF).

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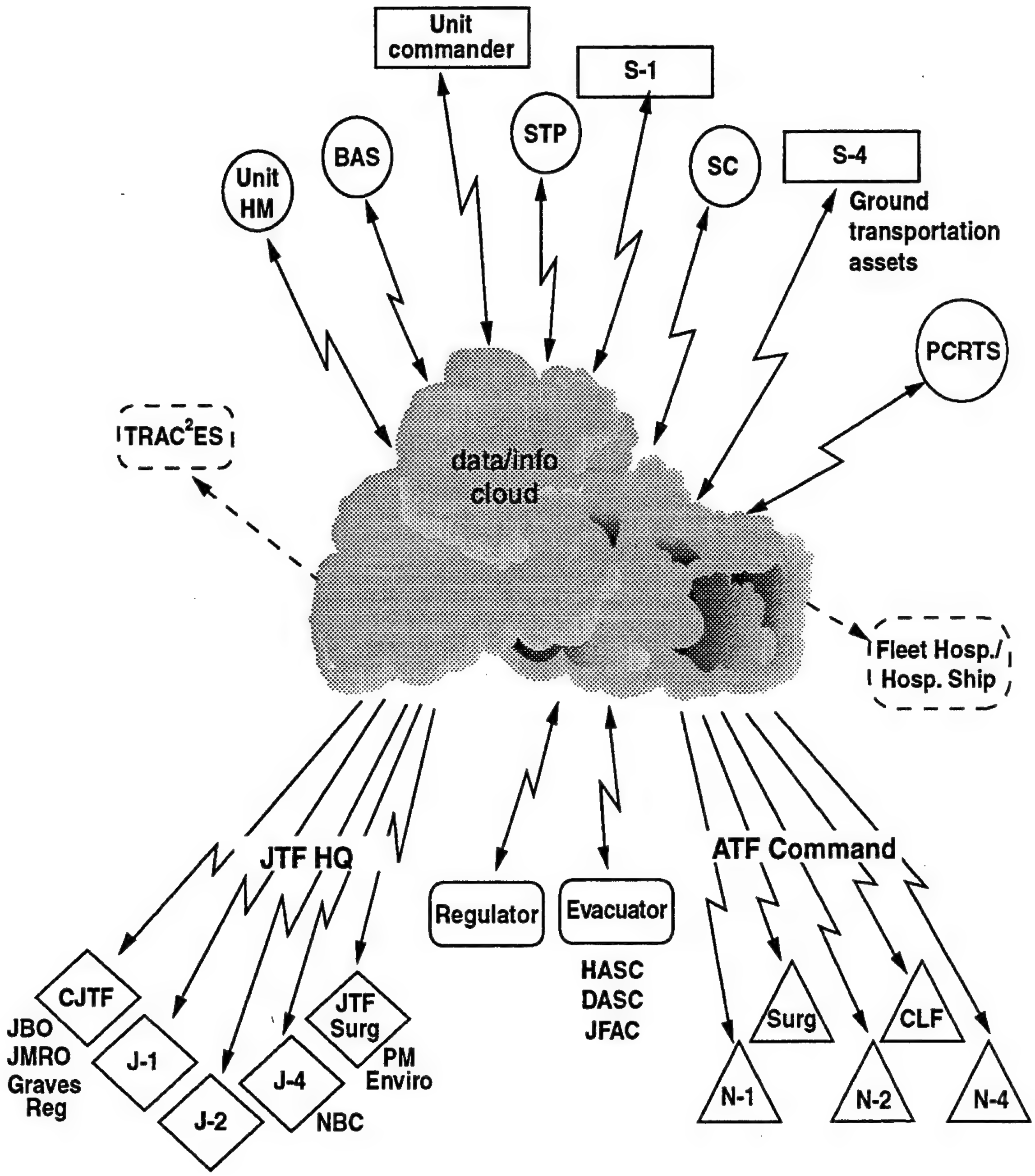
58. In chapter 3, we provided a description of our three medical configuration examples: limited, transitional, and sustained.

59. At this point, it is not clear how the medical regulator (who is usually called the medical regulating coordinating officer, or MRCO) will interface with the emerging joint Medical Anchor Desk. Figure 10 includes the regulator as a placeholder for all regulating functions, including those of the MRCO and medical anchor desk.

Figure 10. Conceptualization of evacuation, regulation, and tracking systems



An important part of this system is that it be able to input to the TRANSCOM Regulating Command & Control Evacuation System ($TRAC^2ES$), which will be following and regulating casualties from as low as echelon III all the way back to CONUS [6]. For example, physicians at echelons IV and V might need to know what medical treatment occurred at echelons I and II.

Combining the information from figure 10 with the specific information requirements for regulating and tracking casualties, which we present in appendix D, gives a detailed sense of the information to be input (both in content and form), the people who input data to the system, and those who would primarily rely on read-only capability for the system.[60] Main data elements include casualty identifiers, how soon the casualty requires evacuation, where the casualty is going, and operating status of medical treatment facilities.[61] Main system users include treatment nodes, command headquarters, transportation commands, and regulators. (See appendix D for details.)

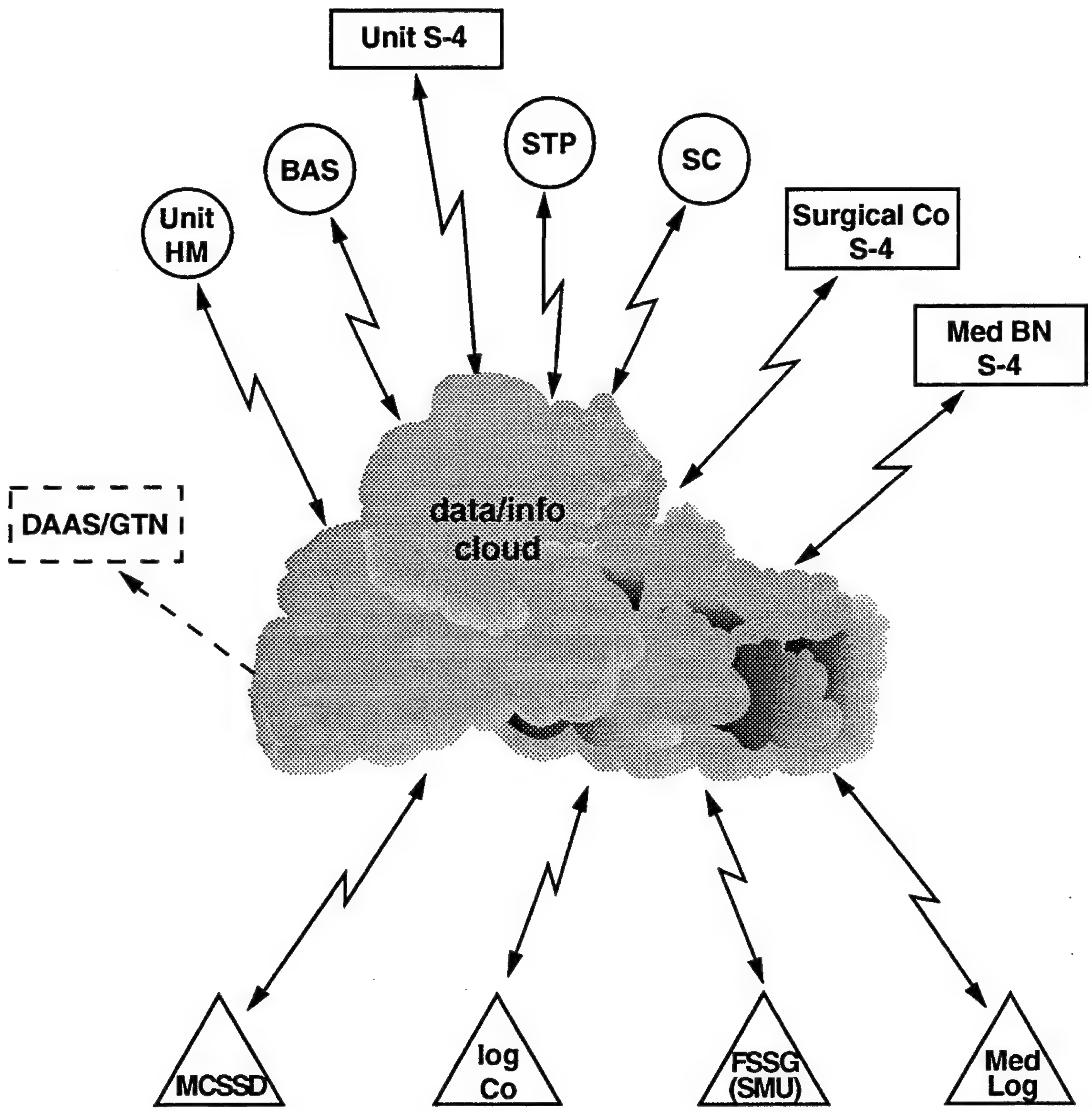
Medical supply system

Figure 11 depicts a data information system that supports field medical supply logistics in the sustained configuration. It shows that all treatment facilities, starting with the BAS, will be able to input orders and access information from the system. An electronic bulletin board can be created and maintained by the FSSG using information from the data cloud. This data bulletin board would allow all interested parties continuous access to the status of medical supply orders in the

60. Figure 10 illustrates the *sustained phase* only. The *transitional phase* would have fewer treatment facilities (because BAS, STP, and surgical company would not be there, although the highly mobile surgical company would be). Limited or transitional situations would probably have fewer of the headquarters and other nodes in the figure. The *limited phase* diagram would be extremely simple because there is no true regulating in a system where the casualty has only one place to go (the PCRTS).

61. The large number of information elements in appendix D indicates the need for development of interfaces to present only relevant information in an organized fashion to avoid information overload.

Figure 11. Conceptualization of medical supply system



system. The system will allow a "push" of anticipatory ordering, in which the provider tells the user what he is sending to that user. The advantage of this anticipatory push is that medical can be lighter, carrying less buffer stock or bulk storage. Voice communication is a backup in case the bulletin board goes down and to make sure that errors are corrected.[62]

Appendix E sketches the content and form of information going into the system. Significant nodes for supply are the MTFs, the medical logistics company, FSSG, MCSSD, and logistics company. Main data elements include name and location of unit ordering the supply, priority of the order, approximate delivery date wanted, confirmation the order was received, approximate date/time of delivery to the logistics officer, and approximate date/time of delivery to the MTF. As with regulating and tracking systems, this system must be compatible with joint-service systems to provide in-transit visibility [6]. The S-4s should also be included in the system because they will deliver orders to the MTF once they have received the supplies from the MCSSD.

Treatment system

In the previous chapter, our analyses showed that *training* is the most important information element in a treatment system from point of injury through the STP. As we said, training is particularly helpful because it can be accessed immediately, it weighs nothing, and it takes

62. The communication system for the *transitional configuration* would have only three possible treatment nodes (unit HM, mobile surgical unit, and PCRTS)—making it considerably less complex than figure 11. It is much less likely to have a CJTF in a conflict of the size described in our transitional configuration. The *limited configuration* system would be even less complicated, with only HM and PCRTS as treatment nodes, and there would not likely be a JTF in such a small conflict. The transitional and limited configurations could still have the basics of the communication system outlined in figure 11 and appendix E (i.e., an electronic bulletin board). However, especially for the limited scenario, medical supply functions may be fully integrated with other logistical systems for supplying the warfighter. For example, if supply caches are used, they might include medical supplies.

up no space. In this section, we develop a *treatment net* for those times when training needs to be augmented.

Training

For a treatment system, unlike the regulation/evacuation/tracking system and medical resupply system, training is a vital information source. We conclude this because we found that communications are basically a backup to the training that everyone should receive in how to handle casualties, from the casualty himself (who might need to self-administer first aid), fellow infantryman, and unit corpsmen, up to the MTFs. This is because our analyses show that an adequate training system will allow most caregivers to deliver care quickly and efficiently—and because people should be expected to provide treatment for which they have been given training. The consultation capability of this system is primarily to help in cases where time is *not* of the essence, and in cases where the difficulty of the task is in assessing and diagnosing what needs to be done. The *data* portion is intended to make it easier to record patient and treatment information and to provide important patient history.

A treatment net

Traditionally, different treatment nodes (such as the surgical company and PCRTS) have *not* had a dedicated communication system except for the regulating net. Earlier, we described an improved version of such a net. The *regulating* net, however, is *not* intended to allow medical providers to consult with one another about treatment decisions.

Treatment consultations might include whether a casualty is a chemical or biological hazard, critical symptoms, and dispensation (e.g., whether evacuated). In contrast, primary information about how to spot a potential chemical/biological hazard would be part of training. Data communications would reveal whether a casualty has a drug allergy,[63] and voice communications could be used secondarily or as

63. Data systems could also include transmitting diagnostic data from medical sensors, if Navy medicine determines such sensor information to be a requirement in the future.

backup for all treatment information. Appendix F gives detail on the content and form of the *treatment* information to be available in the system for the sustained configuration.

Voice

While training is a primary source of information in a treatment system, *voice communication* is the central form carried electronically for telementoring and teleconsulting. This voice system is represented in figure 12, for each of the three scenarios. Voice consultation capabilities will be provided to unit corpsmen and to teams functioning without a corpsman. At the MTFs, this capability will be given to the most highly trained medical caregivers at each site. This includes physicians, independent duty corpsmen, and physician's assistants at the BAS and STPs; surgeons and other physicians at the surgical companies; and all caregivers at the HMSU. Caregivers will primarily consult with physicians and specialists closest to their site of care. For example, in the sustained scenario, a unit corpsman would consult with the battalion surgeon at the BAS; in the limited scenario, the unit corpsman would consult with a physician on the PCRTS. The capability to transmit still imagery to aid in consultation or video teleconferencing capabilities may be available at the surgical company, but not before. Again, this is because we found that image and video were rarely needed before treatment at a fixed surgical facility.[64] Depending on the ultimate requirements of the surgical company and the cost, we allow for the possibility to transmit still imageries, such as EKGs and X-rays, as well as VTC for general and surgical consultations.

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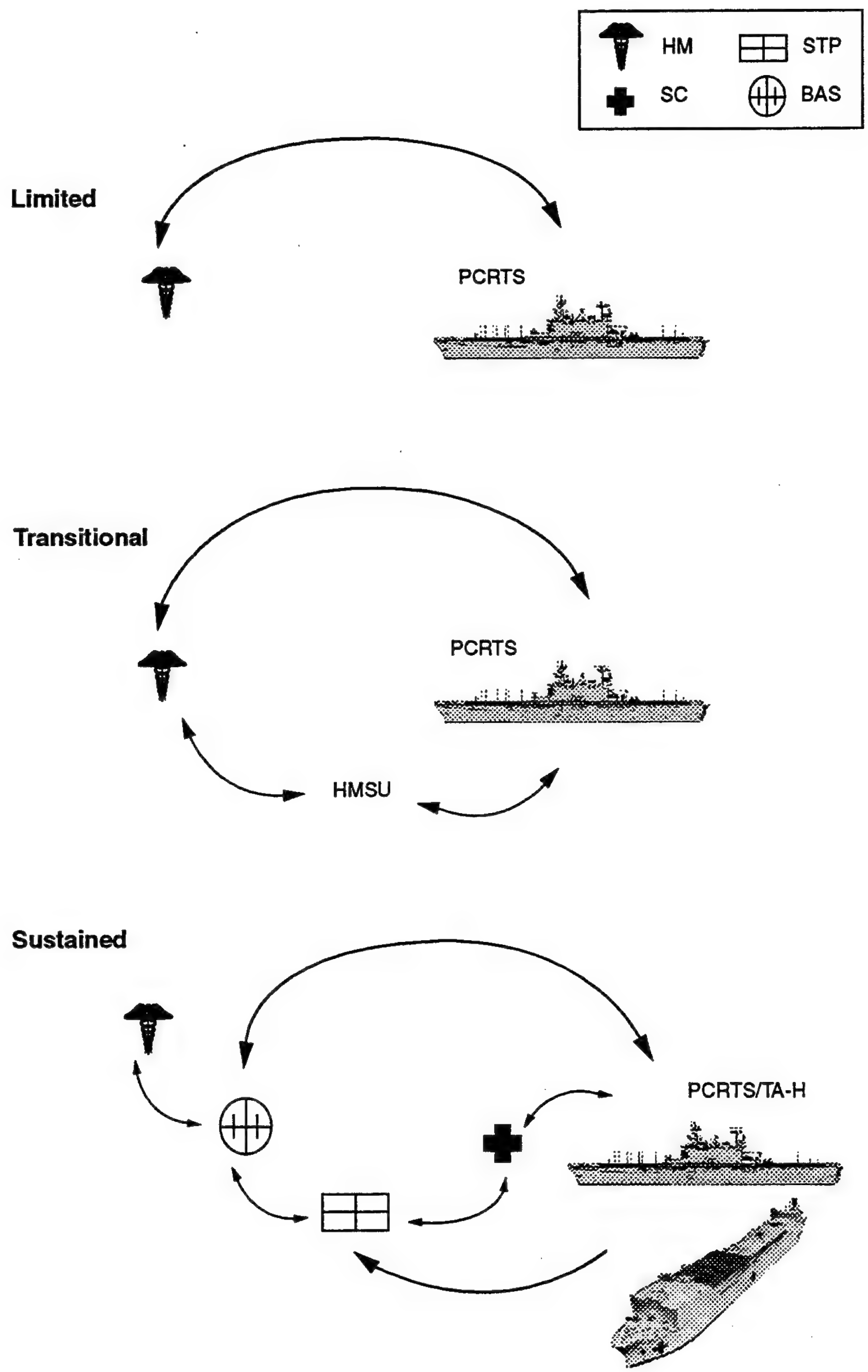
64. Our conclusion about image and video in time of war or conflict is also based on the expense of bandwidth requirements for such a system (in terms of available capacity and dollars). In time of war, bandwidth is heavily taxed by intelligence, which truly does need information in the form of images. As stated earlier, the fact that we did not find image or video to be a requirement for treaters close to the site of initial injury is a separate issue from whether those forms of information are required aboard ships, or even at fleet hospitals.

Figure 12. Primary communication nodes for treatment consultation/mentoring system



Data

While voice is the primary form of consultation communication for the treatment system, we have low-rate data as the primary form of information for certain other aspects of treatment. For example, *prevention decisions,* such as whether troops need immunizations, should have considerable data information from such providers as AFMIC, DIA, or disease vector teams. This information will be pushed to and pulled by physicians and corpsmen from the data cloud. For another example, *medical information* that reports a casualty's drug allergies, blood type, and relevant medial history (e.g., diabetes) will be available immediately to a health care provider in the form of data. Preferably, this information would be kept on the individual using some form of smart card technology. More substantial patient information could then be accessed via the data cloud, which would include the casualty's complete *medical record.* Treaters would have write capability to both of these patient data sources. This would allow them to input data regarding patient condition and any treatment given, thereby informing any subsequent health care providers.

Operational considerations

As we said earlier, to be operationally adequate, information and communication equipment must be durable, usable, reliable, and secure. Equipment that fails on any of these criteria will be considered inadequate for use in the field.

Through its Advanced Warfighting Experiment, the Army has tested telementoring and teleconsulting technologies in the field, using a voice-activated microphone that allows a corpsman to ask for advice without having to use his hands for the radio [24, 25]. The main findings from the Army work indicate the possible strengths and weaknesses of the treatment information system we have just described.

The Army found that telementoring will expand the number of procedures that can be completed at or near the site of initial injury by Army corpsmen. However, the voice-activated equipment that the Army tested had difficulty with:

- Being oversensitive to voice activation, sometimes resulting in having an unwanted open mike
- Operating on the move.

Furthermore, Army participants worried that the equipment they used might be susceptible to jamming and locating techniques. It remains to be seen whether the equipment can be developed that has the durability and other characteristics that operational personnel want in their communicators. The Army also found that it was difficult, initially, for medical personnel to maintain enough communication discipline to keep their conversations short.

If used in isolation, telementoring and teleconsultation cannot succeed. We found that the following will be prerequisites for the successful use of teleconsultation and telementoring to support the new battlefield concepts:

- Corpsmen and other medical providers getting more emergency care training
- Improving the range of conditions that battlefield medical equipment and supplies can assess and treat.

Conclusions

Focus groups were our primary source for sketching a communication system that will meet the requirements of field medical support in the future, including who needs to talk to whom and the required form of information. We also relied heavily on data sets for many of our judgments, especially about the number of troops likely to sustain injuries, the types of conditions requiring treatment at site of injury, and about time to death. The next chapter will explore, in technical detail, how the needs expressed by the focus groups could be met with information and communication technology, piggybacking as much as possible on systems that the Navy/Marine Corps warfighters will have in the future. The next chapter will also illustrate the costs and feasibility of alternative ways to meet information requirements through different configurations of communication systems.

Chapter 6: Medical communication requirements

In this chapter, we evaluate the medical communication capacity needed to meet those requirements specified in chapters 4 and 5. We discuss in detail the assumptions and the methodology we used to estimate the capacity requirements. We also discuss their implications in terms of potential costs (dollars and capacity/bandwidth) and feasibility (the ability of developing technologies to support these requirements).

Scope

Here, we provide broad estimates of medical communication capacity requirements of Amphibious Task Forces (ATFs) of the 2005 to 2015 time frame. Broad estimates are often the only appropriate long-range predictions because of the lack of available details on future systems, networks, and their applications. Broad estimates, such as those provided in this memorandum, are a necessary first step for high-level conceptual planning. Once policy-makers decide on the general outline of a system, it will be appropriate to collect the detailed information required to develop technical specifications.

In this chapter, we estimate the capacity needed to maintain medical information and communications among medical care providers in the field (including voice, data, image and video requirements).[65] We do not include in our estimates the requirements for medical communications from ship to ship and between ships and echelon III and above providers. We decided to limit our scope because GTE's

65. Specifically, these include medical care providers at the site of injury, the Battalion Aid Station (BAS), Shock Trauma Platoon (STP), Highly Mobile Surgical Unit (HMSU), surgical company, and PCRTS.

recently completed Pacific Command (PACOM) Health Care Bandwidth Requirements study [8] addresses echelon III and above requirements. More specifically, the GTE study considered the requirements for medical communications between health care providers starting at the PCRTSs through CONUS tertiary care facilities (echelon V). Both the GTE study and our study used the same methodology and similar scenarios in estimating the communication requirements. For all of these reasons, the studies complement each other well. Together, they address the medical communications for all levels of care with minimal overlap.

Assumptions

To estimate the medical communication capacity requirements for the systems laid out in the last chapter, we made assumptions on the communication equipment, computers, and characteristics of the communication architecture of an ATF. We based our assumptions on the following:

- The communication architecture required to support the Sea Dragon concepts as envisioned by the Commandant's Warfighting Laboratory
- Extrapolation of current and planned military information infrastructure
- Promising communication equipment and capability that are currently in research and development.

Assumption 1

Individual units, including individual teams and corpsmen, will be equipped with handheld computers with integrated communicators. These handheld devices will have low power consumption rates. For average uses, a fully charged battery pack will last at least 12 hours. The communicator will be capable of the following:

- Operating in a circuit-switched or dial-up network. That is, the communicators will establish and maintain communication links only when necessary. This allows a large number of devices

to share a much smaller number of communication channels. This network will operate much the same as the cellular or wireless telephone networks of today.

- Employing broadband code division multiple access (CDMA) schemes. This feature allows more callers to use the system simultaneously without increasing the bandwidth. It also offers enhanced security through inherent antijam, low-probability-of-detection (LPD), low-probability-of-intercept (LPI), and low-probability-of-exploitation (LPE) features.[66]

- Supporting digital data communications at 4.8 Kbps (kilobits per second) and digital voice communications at 16 Kbps.[67]

The computers will be capable of automatically performing the following tasks:

- Initiating communications links

- Voice recognition allowing hand-free operations of the computers for the operators

- Tracking and monitoring each unit's supply situation

- Receiving, processing, and displaying force status broadcasts

- Generating unit's status reports.

Currently, ARPA is assessing the suitability of these types of handheld communication devices and broadband CDMA for medical use in the MARCARD program [27]. MATMO is investigating the use of computers with voice-recognition capability in support of its Meditag program [28].

66. With LPD/LPI features, it would be extremely difficult to detect the communication signals and exploit them to triangulate on the transmitting device. (See appendix B.)

67. The data rates of 4.8 and 16 Kbps are available with many of today's cellular systems. These rates will be available with wireless telephone systems that are being planned, most notably the satellite-relayed Iridium, Globalstar, and Odyssey. These systems should be in full operation in the 2000-2015 time frame [26].

Assumption 2

Higher echelon units, such as the surgical companies and ships, will be provided with high-capacity communication equipment. This equipment will be used to maintain high-capacity communications, such as video teleconferencing (VTC), between higher echelon units.

Assumption 3

The communication network of the ATF will consist of two portions, or subnetworks. One subnetwork will consist of low-data-rate communication channels only (below 64 Kbps). Specifically, each channel will support digital data communications at 4.8 Kbps and digital voice communications at 16 Kbps. The handheld device discussed above will allow access to this subnetwork. Because there will be hundreds of users with these devices, there will be on the order of tens of thousands of possible interconnections for this subnetwork. For this reason, it will provide *circuit-switched services* only. That is, the subnetwork will behave as cellular networks of today. It will assign one available channel to a caller/receiver pair for the duration of their call only. After the call has been completed, the subnetwork can assign the channel to another pair of callers.

The other subnetwork will consist of high-capacity communication channels (64 Kbps or above). Only the surgical companies, ships, and other major units of the ATF will participate in this subnetwork. Although they can be either line-of-sight or satellite-relayed, most high-capacity communication channels are of the latter type because they place less restrictions on the users. Further, high-capacity communication channels can be dedicated or switched. Unlike switched channels, dedicated channels are maintained at all times even when they are idle and carrying no data. At present and in the foreseeable future, high-capacity switched services are available via satellites only

at data rates of 64 Kbps.[68] Because this study needs to address a broad range of communication needs of future ATFs, we assume that this subnetwork will consist of *satellite-relayed dedicated communication channels* only.

Assumption 4

All computers that are collocated at a given site, such as shipboard computers, will be connected into one or more Local Area Networks (LANs). Further, all the LANs within the Task Force will be interconnected into a seamless, robust, and transparent network. The network will ensure that each unit of the Task Force will have access to the information it needs, in accordance with its need-to-know, regardless of the unit's location, size, position in the command echelon, and where the information resides. We depict this network as an "information cloud" in figures 11 and 12 in chapter 5. All interconnections between every unit, switched or dedicated, point-to-point or broadcast, are represented as interconnections between the units and the cloud. The cloud will have sufficient intelligence to route information between the units and all intended recipients.

Assumption 5

The "anchor desk" and the "smart push/user pull" concepts, which are being promoted today, will be implemented. In the smart push/user pull concept, selected information will be pushed to the users as they specify. The users can retrieve additional information when required. Under this architecture, the medical anchor desk will collect and process all medically relevant information available to produce and maintain an accurate and up-to-date composite picture of the medical situation of the ATF. The medical anchor desk will

68. One notable exception is the Geodesic system, which proposes to launch 840 satellites plus 84 spares in 2 years. This represents one-half of the total launches of the world in these 2 years. Geodesic plans to provide communication channels with data rates up to 2,048 Mbps starting early in the next century. As of the end of 1995, Geodesic has about $20 million of the more than $5 billion it believes it needs to complete the project. We do not base our analysis on the existence of this system to support the communication requirements of future ATFs.

disseminate this composite medical picture both within and outside the ATF. This is accomplished by periodic broadcasting of summarized or value-added products, such as the various status boards that are currently maintained, evacuation schedule, etc., that will be generated by the anchor desk. The users can connect to the ATF network and extract additional information they need. To aid them in their search, the users will have access to "net browser" software and electronic "information agent" with artificial intelligence.

Methodology

Overview

In this study, we adapted the needline analysis approach to estimate the medical communication requirements of an ATF. The Intelligence and Communications Architecture (INCA) Project Office, Intelligence Programs Support Group (ISPG), developed the needline analysis methodology as part of a framework for planning communications support to a deployed Joint Task Force [29].

In the needline analysis approach, the network consists of a number of dedicated point-to-point communication channels linking pairs of users. Each channel is a needline that carries data only. The average capacity requirement for a given needline is the data rate required to carry the information that is exchanged over the needline in a single day, assuming that the information is distributed evenly throughout the day.

A needline with a capacity equal to its average capacity requirement will not be able to keep up with traffic demand because the instantaneous rate of information exchange is not constant. *The amount of information exchanged over a needline in one hour varies from hour to hour and could greatly exceed the average value.* If a needline has the capacity to handle the traffic demand of the peak hour, it would be able to handle all traffic demands throughout a day. This data rate is referred to as the peak capacity requirement.

The total average (peak) capacity requirement of a network is the sum of average (peak) capacity requirements of all needlines in the network.

Calculating requirements

As stated above, we assume a medical network (at the ATF-level) that consists of *high-capacity dedicated* and *low-capacity circuit-switched or dial-up* communication channels. In addition, each channel or needline will carry both voice and data traffic. Therefore, we adapted the needline analysis approach to take both of these differences into account.

In our approach, we first estimate the *net loading*, which we define as the amount of time in a day the network will be used to exchange all necessary information. This is the *equivalent of the total amount of information transferred over the net in a given day* used in the basic needline analysis. The *communication capacity requirement* of the network *is the capacity needed to satisfy the estimated net loading*. To select the required network capacity for a given net loading, we use the selection criteria developed by the telephone industry.[69]

Estimating net loading

There are two modes of communications: store-and-forward and conversational. In store-and-forward communications, the transmitted information is stored by the network and later delivered to the recipients. The time delays between the message transmissions and receptions vary but are typically greater than 1 second. Store-and-forward is the preferred mode of communications for data because it is generally much less expensive. The conversational communications require that time delays between transmission and reception be less than 0.6 second. The reason for this stringent requirement on

69. We use a lookup table that Northern Telecom used to provision telephone trunks to its switches [30]. The network capacity is the product of the number of trunks provisioned and the capacity of each trunk. We believe that this provides a good estimate of the capacity because the ATF networks envisioned in this study are small enough to be served by a commercial local switch. These switches typically serve about 10,000 residences.

network response time is the human intolerance for delays. Conversational communications include both voice telephony and VTC.[70]

By definition, we estimate the net loading from store-and-forward or data communications as follows:

$$L_D = \frac{1}{R}\sum_n S_n O_n F_n \tag{1}$$

where the summation is carried over all types of data messages that are exchanged over the network and

where:

L_D = net loading of the network due to data communications

S_n = largest size of data messages of type n in Kbit

F_n = message frequency, i.e., the number of messages of type n that are exchanged over the network in a day

O_n = overhead factor, which includes error-detection and correction codes and transfer protocols overhead. Typically this value is between 2.0 and 2.5 [29]. We use 1.0 and 2.5 as the overhead factors for data transmissions over switched and dedicated communication channels. The reason for this difference is that the overhead is already subtracted from the overall data rate of the former, leaving 4.8 Kbps as the *content* data rate.

R = overall data transmission rate of the communication channel

We calculate the net loading from conversational communications as follows:

$$L_C = T_{\text{voice}} N_{\text{voice}} + T_{\text{video}} N_{\text{video}} \tag{2}$$

70. Technically, highly compressed VTC is not regarded as conversational because of the excessive delays involved. For convenience, we do not make this distinction.

where:

L_C = net loading of the network due to conversational communications

T_{voice} and T_{video} = average duration of a voice and video call, respectively

N_{voice} and N_{video} = number of voice and video calls respectively, that will be made in a day using the switched subnetwork

The net loading of the network, L, is the sum of L_D and L_C.

$$L = L_D + L_C \qquad (3)$$

In the next section, we present our calculations and results.

Results and discussion

The amount of medically relevant information that must be exchanged will be driven by the casualty rates, how the casualties flow through the systems of care, and the medical functions that must be performed periodically. The seven major medical functions identified in this study are:

- Preventing casualties
- Locating casualties
- Clearing and protecting casualties
- Assessing, diagnosing, and triaging casualties
- Treating and sustaining casualties
- Evacuating, regulating, and tracking casualties
- Obtaining medical supply.

For the purpose of estimating medical communication capacity requirements, we exclude the information requirements for the clearing and protecting of casualties because it is already included in the warfighter's requirements. Also, for simplicity, we combine into

one the information requirements for preventing, assessing/diagnosing/triaging, and treating casualties.

Table 2 lists the numbers of casualties for the peak day of the campaign for each of the three scenarios we consider. It also contains the casualty flow from the site of injury (self, buddy, or unit corpsman) through the BAS, STP, HMSU, and surgical company—depending on the scenario. The first and second columns in each scenario contain the percentages of the total casualties and the number of casualties treated at each care site, respectively.

Table 2. Flow of casualties[a] by scenario and site of care on peak casualty generating day

	Limited[b]		Transitional[c]		Sustained[d]	
Site of care	% of total casualties	Number of casualties	% of total casualties	Number of casualties	% of total casualties	Number of casualties
Total no. of casualties[e]		58		288		798
Self/buddy/corpsman	100	58	100	288	100	798
HMSU	n/a	–	17	49	n/a	–
BAS/STP[f]	n/a	–	n/a	–	99.7	796
Surgical company[g]	n/a	–	n/a	–	92	734
Higher levels of care	n/a	n/a	n/a	n/a	45.6	364

a. Casualties include wounded in action (WIA), disease and nonbattle injury (DNBI). Killed in action (KIA) are not included in calculation.

b. Casualties for the limited scenario were generated by CASESTs for a MEU operating in support of a limited contingency operation.

c. Casualties for the transitional scenario were generated by CASESTs for a MEF (Forward) operating in support of a limited contingency operation. Casualty flow was estimated based on focus group, clinical experts, and AMEDD data.

d. Casualty generation and flow information for the sustained operation was estimated by NHRC (for AMAL reconfiguration study) based on PATGEN model for MEF operating in support of MRC worst-case scenario.

e. Total casualties suffered for peak casualty generating day of scenario.

f. STP is combined with BAS for our calculations. Our flow data from NHRC did not include the STP in its calculations. Based on the current definition of the STP and its developing table of equipment, we treat it as an extension of the BAS.

g. To the extent that lifts of opportunity bypass the surgical company, the number of casualties treated at that level might be smaller than shown here. We present these findings as a "worst case" or upper bound of likely workloads. The same is true for tables 3 and 5.

Low-capacity subnetwork

As discussed in the assumption section of this chapter, the low-capacity subnetwork provides low-data-rate connectivity among the field medical providers and between them and specialists at higher echelons of care. This subnetwork consists of a number of low-data-rate channels that are shared or switched among many users as necessary. We assume that their use for medical purposes will be driven by the casualty rates and casualty conditions.

Estimated communication capacity requirements

Table 3 lists our estimates of the number of casualties that may require voice consultations at each care site. We based our estimates on interviews with clinical experts, the study's focus groups, and descriptive analyses of the AMEDD Echelon I and II Clinical Data Base (appendix G discusses in detail the methodology we use to calculate these estimates). For each scenario, the first column lists the percentage of the total number of casualties treated at each site of care that may require voice consultations (this would include teleconsultation for assessment and/or treatment, as well as telementoring). The second column lists the actual number of casualties that this percent represents.

Table 3. Estimated requirement for voice consultation at each site

	Casualties that may require voice consultation for treatment/assessment					
	Limited		Transitional		Sustained	
Site of care	Percentage	Number	Percentage	Number	Percentage	Number
Self/buddy/corpsman	69	40	69	198	22	176
HMSU	n/a	–	17	8	n/a	–
BAS/STP	n/a	–	n/a	–	44	350
Surgical company	n/a	–	n/a	–	35	257

Table 4 presents the maximum sizes and frequencies of medical messages that need to be exchanged over the low-capacity subnetwork to support the medical functions listed. We estimate the maximum message sizes for the evacuating/regulating/tracking, status update,[71] and supply reporting functions based on the recommended standard forms and messages listed in the appendixes of the NAVMED P-5133/FMFM 4-51 Task Force Medical Regulating Manual [31]. The message sizes for locating and monitoring are our estimates based on the type of information that will likely be exchanged to support these functions. For example, for the locating message, the casualty's name, position, time of injury, and some preliminary indication of injury type should be transmitted. For the monitoring message, the casualty's heart rate, blood pressure, temperature, and other vital signs should be transmitted.[72] The voice communications for the treatment function are for consultations during treatments. We base our estimate of less than 5 minutes for each consultation on the AMEDD data (which specifies time needed to complete each task—90 percent were under 5 minutes) and findings from the focus groups.

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71. Status update refers to the summarized or value-added products, such as status boards, evacuation schedule, etc., that will be produced by the medical anchor desk. The purpose of these status updates is to provide an accurate and up-to-date composite picture of the medical situation of the ATF.

72. We did not find monitoring to be a minimum requirement at this time. We do believe that, with advances in medical treatment, such as "suspended animation" for head wound victims, monitoring would become an essential requirement. We include it here for completeness, because of its potential use, and to assess the impact of systems, such as the Personal Status Monitor (PSM), which are currently being developed and considered for such use. We envision this type of message as a means of monitoring the conditions of the casualties while they wait for their evacuations. Currently, the focus groups for this study do not see a requirement for this message. However, we include it here to assess the impact of systems, such as the PSM, that are being considered for such use [32]. In addition, in determining the frequency of calls, we allow for seven monitoring messages to be transmitted for casualties that need to be evacuated. This would allow for a monitoring message to be sent once every 15 minutes for a casualty waiting about 2 hours for evacuation transportation.

Table 4. Sizes and frequencies of messages exchanged over the switched portion of the network

Tasks/functions	Medium	Size (Kbit)/ duration	Frequency
Locating	Data	8	Per casualty
Evac., reg., and tracking	Data	8	Per casualty to be passed to next level of care
Monitoring[a]	Data	16	7 per casualty to be passed to next level of care
Status Updates	Data	48	Once per hour
Supply reporting	Data	8	Per casualty
Treatment	Data	16	Per casualty
	Voice	< 5 min.	Per casualty requiring voice consultation

a. We envision this type of message as a means of monitoring the conditions of the casualties while they wait for their evacuations. Currently, the focus groups for this study do not see a requirement for this message. However, we include it here to assess the impact of systems such as the Personal Status Monitor (PSM), which are being considered for such use [32].

Except for the status update messages, all of the messages will be transmitted on a per-casualty basis. Because every care provider will transmit these messages for each casualty they receive, the medical anchor desk will be able to construct the audit trail for all casualties. Also, the supply situations of each care provider will always be up to date because supply item expenditures will be reported as they are applied to the casualties. For status updates, we assume that the medical anchor desk will broadcast the status of the medical situation of the ATF to all care providers once every hour. Also, as each care provider reports a new casualty, they also receive a new status update message. We do not include this message in table 4 because the communication channel will be full duplex. Thus, information can be transferred from the care provider to the medical desk, and vice versa, simultaneously.

We now have enough information to calculate the net loading of the low-capacity subnetwork. Recall from equations 1 through 3 that this requires the size and frequency of data messages being sent (table 3), and the quantity and duration of voice and video communications required (tables 2 and 3). Table 5 presents our estimates of the net

loading and the communication capacity requirements of the low-capacity subnetwork.

Table 5. Net loading and communication capacity requirements of the low-capacity subnetwork

Scenario/treatment site	Net loading[a] (CCS)			Number of channels (P.01)[b]		
	Data	Voice	Total	Data	Voice	Total
LIMITED						
Point of injury (self, buddy, unit HM)	20.8	120.0	140.8			
TOTAL	20.8	120.0	140.8	4	9	10
TRANSITIONAL						
Point of injury (self, buddy, unit HM)	91.2	594.0	685.2			
HMSU	15.5	24.0	39.5			
Update[c]	2.4	n/a	2.4			
TOTAL	109.1	618.0	727.1	9	28	32
SUSTAINED						
Point of injury (self, buddy, unit HM)	252.2	528.0	780.2			
BAS/STP	236.6	1050.0	1286.6			
Surgical company	232.4	771.0	1003.4			
Update	2.4	n/a	2.4			
TOTAL	723.6	2349.0	3272.6	32	87	115

a. This is measured in hundred call seconds (CCS).

b. The number of channels needed to support the net loadings for each scenario was calculated using a blocking factor of P.01. The blocking factor represents the probability that when a user picks up the telephone he or she will not get a dial tone (meaning all available channels are in use). The lower the blocking factor, the lower the probability that this will happen—lower blocking factors are better for consumers.

c. It is more appropriate to list the net loading for Update as a separate item for the Transitional and Sustained scenarios because it is a broadcast. Only one broadcast is required to reach all units.

The requirement of the low-capacity subnetwork is specified as the number of communication channels needed to support the estimated net loading. This subnetwork is switched, i.e., it allows a relatively large number of users—129 in the limited scenario—to share a much smaller number of available communication channels (10, as shown in table 5). We provision the low-capacity subnetwork with a

Poisson blocking factor[73] of P.01. *The blocking factor is an indication of how well the switched subnetwork responds to user demand.* The lower the blocking factor, the better for the user and the higher the number of channels that must be provided to support a given net loading. For example, the public telephone system in the United States (a switched system) is provisioned with blocking factors of P.01 or better. Except in the case of disasters, only rarely would a user not get a dial tone—the network cannot respond to a user demand. On the other hand, with the Defense Switched Network (DSN), which was a fairly blocked system, a user would frequently be blocked (not get a dial tone) or be preempted during a call.[74]

We separately determined the numbers of channels for data, voice, and total (data and voice together) using the appropriate estimated total net loadings and the selection criteria by the telephone industry [30]. The number of channels in the "Total" (voice and data) column is less than the sum of the numbers of channels for data and voice separately. There are two reasons for this:

- The number of channels is an integer, so we must round up to the next higher integer. For example, 3 and 4 channels are required for net loadings of 15.7 and 29.6, respectively. Our estimated net loading for data communications in the limited scenario is 20.4, which requires a number of channels between 3 and 4. We rounded up to and selected 4. In doing so, in effect, we overprovisioned for the data communication requirements.

- The efficiency of sharing. It is more efficient to let a large user base share one common network than to break the user base into many small ones, each of which is served by a separate net-

73. *Blocking factor* is a term from the telephone industry. It is a Poisson probability that when a user picks up the telephone he will find that the network is fully loaded and there is no trunk available to establish his intended call. That is, he will get no dial tone.

74. DSN will preempt a lower precedent call if a higher precedent call is attempted and all the trunks in the system are busy. This DSN feature ensures connectivity to a subset of critical users in a fairly blocked system at all times. In FY95, DISA started to provision DSN to P.03 to improve service.

work. The reserved capacity of the combined network would be smaller than the sum of the reserved capacities of individual networks.

Implications for the low-capacity subnetwork

As seen in table 5, the MEU in a limited Sea Dragon operation would need 10 beyond-line-of-sight (BLOS) communication channels to support its medical operations during the worst day (casualty-wise). Currently, a three-ship ARG would not be able to dedicate this level of communication support to medical operation. The BLOS communication equipment on a large-deck amphibious ship (LHA and LHD) consists of 12 UHF SATCOM-capable transceivers and 20 to 24 HF transmitters [33]. Furthermore, the current limitation on UHF SATCOM is not equipment but the availability of channels. This problem worsens as we go to the transitional and sustained operations. As we shift from the MEU to the MEF-Forward and the MEF, the number of available radios increases proportionally. However, the number of available channels does not—it is determined by the frequency bands already allocated and the number of satellite transponders already in orbit. The number of channels needed for medical, on the other hand, increases faster than the increase in the sizes of the ATF.[75]

In the near future, the DOD will field the small-size Demand Assigned Multiple Access (DAMA) equipment. The use of this equipment allows one UHF SATCOM channel to be split into 15 subchannels, each of which can serve a distinct communication net. With this configuration, it is theoretically possible to provide the required channels

75. The estimate of the requirements for the low-capacity subnetwork may represent an overestimate in the sustained scenario. We are allowing consultations at all three echelons of care. As such, consultations would be repeated for some casualties. This is redundant and drives up the requirements. This is evident from the fact that the requirements for the Sustained scenario are more than proportionally larger than the other two scenarios. On the other hand, we may be underestimating the human tendency to establish voice conversation with others during times of stress (reflected in the percentage of casualties requiring voice consultations) and the duration of such calls. As such, we decided to err on the side of caution and let the estimate stand as shown in table 5.

for medical uses.[76] However, because of the small bandwidths of the UHF SATCOM channels (5 and 25 KHz), each subchannel will not be able to support the 4.8-Kbps data rate for data and 16-Kbps rate for voice. If the channel data rate for data is reduced, more channels would be needed to carry the required information. For voice, reduced data rate sacrifices voice quality and recognition. The current DOD procurement plan will not provide enough of this equipment to fully equip Marine forces at the infantryman, or even the team level, as envisioned by the Commandant's Warfighting Lab. Further, the DAMA equipment and radios are bulky and have high energy consumption rates, making them unsuitable for limited and transitional operations, i.e., extended operations in the field with minimal support.

The only communication system that may provide the required medical capacity is the *broadband CDMA wireless technology*. The industry is actively conducting research and development on this technology to provide the needed capacity to the rapidly growing wireless communications. The DOD, however, is not yet actively engaged in research and development in this area. The Warfighting Lab envisions adapting the equipment for one commercial wireless base station to be put on board high-flying, long-endurance unmanned air vehicles, balloons, and/or low- or medium-earth-orbit satellites. The modified base station will use the entire 12.5 MHz currently allocated to each cellular provider in a market. Assuming each channel will be using the 30-KHz bandwidth of today's cellular system, each modified base station can theoretically support *1,270 channels simultaneously* [34]. Further, the handheld communication device mentioned in this study can easily be adapted from the cellular phones or Personal Digital Assistants (PDA) of today. These devices are small enough and have reasonably low power consumption rates.

76. A total of 808 UHF SATCOM channels are available worldwide. With DAMA equipment, there will be 12,120 (808 x 15) subchannels. Assuming these are evenly distributed over the world, there can be 2,424 subchannels within each of the five main theater areas of operations (AOR) or main satellite footprints (the Western and Eastern Pacific, the Western and Eastern Atlantic, and the Indian Ocean).

It should be noted that the major part of the capacity requirement for the low-capacity subnetwork is due to the requirement for teleconsultation and telementoring, i.e., voice communications. The net loadings for data communications are less than 25 percent of the total for all three scenarios. In fact, data communications can be increased substantially without putting burdensome demands on the communication network.

There are three ways to reduce the capacity requirements due to voice communications. The most effective way is to reduce the number of voice consultations. This can be done through training. A highly trained care provider will more likely know what to do under most circumstances. Therefore, he will be less likely to seek consultation because it would require time and detract from the tasks at hand.

A second way to reduce reliance on voice communication would be to use data capabilities, such as e-mail, for consultations rather than voice. Voice requires more communications capacity than does e-mail.

A third way to reduce the requirement is to decrease the grade of service, i.e., increase the blocking factor. In effect, we increase the chance that a user who wishes to make a voice consultation is denied this service. If this occurs often enough, a user will be more likely to assess whether he really needs to initiate a consultation. The danger in this method is that the degraded network may not be able to satisfy the actual requirements.

To mitigate the effect of a highly blocked network, one can introduce the preemption capability similar to the DSN. Preemption capability allows the network to terminate an ongoing low-priority call to establish a new call at higher priority when all of the communication channels are in use. This capability requires a set of priorities that can be pre-assigned to equipment or dynamically assigned to calls. For example, the network can limit a subset of equipment (e.g., the handheld devices assigned to providers at point of injury) to certain priorities. This has a distinct disadvantage because no preassigned priority scheme can be appropriate for all situations. For medical applications, the consequences of terminated calls due to the inappropriately assigned priorities can literally be life or death. Alternatively, the

network can allow a priority to be assigned to each call (e.g., based on the type of injury) by the originator. This method is more flexible but requires the user to select the appropriate priority. As shown by experience with DSN, appropriate priority selection requires user training.

The preferred solution to reducing network requirements is to find a balanced compromise between restricting use and reducing the need to use through enhanced training.

High-capacity subnetwork

We now consider the capacity requirements of the high-capacity subnetwork. As discussed in the assumption section of this chapter, the participants of this subnetwork will be the surgical companies and higher echelon care providers. Each of these units will be equipped with a satellite-relayed dedicated communication channel. In this section, we will estimate the appropriate data rate for these communication channels.

Estimated communication capacity requirements

We see telemedicine as the only medical application that requires high-capacity communications.[77] Further, based on our findings, telemedicine, if required at all, would only be initiated as far forward as the surgical company. Therefore, we estimate the maximum sizes and frequencies of the medical information products that might be exchanged over a dedicated point-to-point communication channel between a surgical company and higher echelons of care. These include video teleconsultation, electronic transfer of patient records, and imageries, such as EKGs, teledermatology, and teleradiology. Table 6 presents these findings.

77. For our purposes, we look at a fairly narrow range of telemedicine capabilities, including video teleconsultation, electronic transfer of patient records, and imageries, such as EKGs, teledermatology, and teleradiology.

Table 6. Sizes and frequencies of information products exchanged over each dedicated link

	Medium	Sizes (Mbit)	Required rate (Kbps)	Suggested applications	Frequency of use
Conversational	Voice[a]	<5	16	General consulting	N/A: use switched service
	Video	<10	128	General teleconsulting	30% of surg. cases (12 per day)
		<30	768	Surgical teleconsulting	15% of surg. cases (6 per day)
Store and Forward	Data	8	n/a	Electronic transfer of patient records	Per casualty (86 per day)
		1	n/a	Electronic transfer of EKG	Casualties not RTD (3 per day)
	Imagery	8	n/a	Teledermatology	Casualties not RTD (2 per day)
		63	n/a	Teleradiology	Surgical cases required VTC (48 per day)

a. Voice consultation has been addressed previously in the discussion for the low-capacity subnetwork. It is included here only for completeness.

In this study, we allow for two types of video consultations—compressed (128 Kbps)[78] and full-motion (768 Kbps). The compressed VTC will be used for general consultations before or during noncritical surgeries. The full-motion VTC will be used to allow the surgeons to consult with specialists during a major surgery. We estimate the average duration of the video consultations as one-third of the time required to complete the most complex medical task as specified in the AMEDD data.

78. Although highly compressed VTC is available at 64 Kbps, the compression technique involved introduces significant loss of video fidelity in addition to several seconds of delay. To be conservative, we decline to use this type of VTC for general consulting for medical purposes.

The maximum sizes for the imageries are estimated from the following assumptions:

- For low resolution[79] imageries, such as EKG, the basic image will have 1,024 X 1,024 pixels, each with 1-bit color (black and white).
- For medium resolution imageries (e.g., teledermatology), the basic image will have 1,024 X 1,024 pixels, each with 8-bit color or gray-tone scheme.
- For high resolution imageries (e.g., teleradiology or X-ray), the basic image will have 2,560 X 2,048 pixels, each with 12-bit color or gray-tone scheme. This is the currently accepted diagnostic quality X-ray.

We estimate that the average size of a patient record is 8 Mbit (megabits), equivalent to about 500 typed pages. These data will be transferred for each casualty received at the surgical company. For the low- and medium-resolution imageries, such as EKG and teledermatology, we assume that this imagery will be electronically transmitted only for those patients who require such imagery *and* will be transferred to the next echelon of care.[80] From the AMEDD data, we found that, of casualties received at the surgical company, less than 1 percent (0.63) will need an EKG to be interpreted by an M.D. Of these casualties,

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79. Technically, resolution refers to the number of pixels an image has. However, color depth affects the viewer's perception of resolution. For example, a picture on a TV screen seems more continuous, i.e., has higher resolution, than the same picture on a computer monitor. The latter actually has higher resolution than the former. The TV, however, has much higher color depth than the computer monitor (256 colors, typically). In this report, we use the term *resolution* to refer to the perceived resolution, which includes number of pixels as well as color depth.

80. We use transfer to the next echelon of care as a proxy for severity of disease or injury. We assume that only the more severe cases would require electronic transfer of EKGs and possibly teleconsultation for dermatological cases. In addition, this assumption subsumes the requirement that required imagery be transferred with the patient to any subsequent care facility.

about half will be returned to duty and half will be transferred to a higher echelon of care. Similarly, approximately 5 percent of casualties received at the surgical company represent dermatological cases, and all but 5 percent of these subsequently return to duty. Therefore, teledermatology and EKG requirements would both represent approximately 0.3 percent of the surgical company's total casualties in a given day. Finally, for teleradiology, we assume that these imageries will not be electronically transmitted unless absolutely necessary because of their large size. More frequent transmissions of teleradiology imageries will quickly overload the capacity of the communication channels. Therefore, we assume they will only be transmitted for patients whose surgeries require video consultations.

We estimated that 30 percent and 15 percent of the casualties who will receive surgeries at the surgical companies will need compressed and full-motion video consultations with specialists, respectively.[81] From table 2, the three surgical companies in the sustained scenario will receive a total of 734 casualties. Also from the AMEDD data, we find that 16.76 percent of these casualties will receive surgeries. Because there are three surgical companies, each will have to perform a total of 41 surgeries. Hence, the number of casualties who need compressed and full-motioned VTC consultations are 12 and 6, respectively. Further, we estimated that 2 and 4 definitive teleradiology

81. These estimates are based on our analysis of the AMEDD data, and interviews with Navy medical experts. Based on these interviews, AMEDD surgery cases for echelon II (which mainly reflect those surgical procedures performed at the Army's Forward Surgical Team facilities) are lower than those expected at a Navy Surgical Company. This is because the Navy's surgical companies perform an expanded range of procedures. Based on historical data, about 30 percent of casualties suffer from severe wounds (requiring surgical intervention at a surgical company, opposed to the 17 percent from the AMEDD data) and 10 percent of those (or 2.5 percent of all casualties) would require operations for life or limb salvage. Based on this information, we assume that 15 percent of casualties requiring surgery may require full motion video consultation with a specialist (orthopedic, cardiothoracic, or neurosurgeons at tertiary echelons of care), and about 30 percent may require compressed video consultations with physicians aboard the PCRTSs or hospital ship or at a fleet hospital.

imageries will also be transmitted to the specialist before general and surgical consultations, respectively.

Table 7 presents the net loading and the utilization rate of the dedicated link assigned to a surgical company. We calculate the net loading using 786 Kbps as the capacity of the dedicated channel. The utilization rate is simply the ratio of the net loading to 24 hours.

Table 7. Net loading and utilization rate of each dedicated link[a]

Information transfer medium	Sizes of transfer (Mb/minute)	Required data rate	Net loading (minutes)	Utilization rate (percent)
Voice	<5	16	n/a	n/a
Video	<10	128	20	1.4
	<30	768[b]	180	12.5
Data	8	n/a	38	3.1
	1	n/a	0	0.0
Imagery	8	n/a	1	0.1
	63	n/a	165	11.5
Total			404	28.6

a. Assumes each dedicated link has minimum capacity of 768 Kbps.

b. Assume that the loss of video fidelity due to compression at this data rate is adequate for surgical teleconsultation. This assumption is necessary because the medical community has not specified a standard for VTC for surgical teleconsultation.

Implications for the high-capacity subnetwork

A utilization rate of 30 percent or more is necessary to justify a dedicated channel. It is, however, not economically efficient to operate the channel at this low utilization rate. From an efficiency point of view, the utilization rate should be greater than 70 percent.[82]

82. This is a rule of thumb used by the telecommunication industry [35].

This leads us to two important issues that must be addressed:

- If a high-capacity dedicated channel is warranted, what is the minimum capacity it should have?
- What is the optimal way to configure the high-capacity subnetwork to realize maximum savings in recurring costs?

Minimum capacity. To address the first issue, we will estimate the minimum capacities for two cases: (1) VTC is not required and not provided and (2) VTC is required.

If VTC is not required and not provided, then the only means of teleconsultation would be to first exchange the necessary still imageries and then hold voice consultation.[83] Using the requirements listed in table 6, without the voice and video requirements, we estimate the total net loadings and total utilization rates for channels with given data rates. These are estimated for several given data rates, in increments of 64 Kbps, in table 8.

Table 8. Total net loadings and utilization rates for various channel data rates and without full-motion VTC

Data rate (Kbps)	Net loading (minutes)	Utilization rate (percent)
64	2,429	168.7[a]
128	1,215	84.4
192	810	56.2
256	607	42.2

a. Utilization rate of higher than 100 percent means that the channel does not have sufficient capacity to transmit all the required information.

83. While we identified the need for enhanced consultation capabilities at the first fixed surgical site (here assumed to be the surgical company), it is unclear what level of technology is necessary to fulfill this requirement. Therefore, we examine the cost of supplying video consultation or consultation capabilities relying on transfer of still imageries.

As seen from table 8, the optimal choice is one channel of 128 Kbps or two channels each with a data rate of 64 Kbps. These two options combine the lowest possible data rate with utilization rates sufficient to ensure efficient use of the link. For the foreseeable future, the choice of a channel with data rate of 128 Kbps will require a dedicated service. The other choice is more desirable because it can be accomplished with switched service, which is both less expensive and is always available. The International Maritime Satellite Organization is offering worldwide INMARSAT-A service at 64 Kbps. The equipment cost is about $30,000 to $40,000 and the use rate is between $4 and $10 per minute. The switched option is also preferable to the single dedicated channel option in cases where a surgical company needs to function as two separate entities instead of a single unit (split-basing).[84] If this option is selected, the entire network, high and low-capacity, will consist of switched channels.

If, on the other hand, VTC is determined to be a requirement at the surgical companies, then it will determine the required data rate of the channel. This is so because full-motion VTC requires significantly higher data rates than what is needed for data transmissions. To examine the effect of using VTC data rates lower than 768 Kbps, we make the assumption that a new, more advanced, video transmission standard, the ITU H.261,[85] will be available. We also made an implicit

84. The capability of surgical companies to split in two is a feature of the newly reorganized medical battalion. If the surgical company was outfitted with a dedicated-link for communication, both halves of the surgical company would have to be outfitted with an antenna and transceiver in order to share the link. This would be costly in terms of dollars and loss of mobility for the surgical companies.

85. The H.261 standard is being developed by the International Telecommunication Union (ITU) for video transmission at p x 64 Kbps (p = 1, 2..., 30) data rates. It specifies real-time encoding-decoding with delay less than 150 ms. The picture frames are noninterlaced with an input rate of 29.97 frames/s (full-motion). Note that when p = 12, the data rate is 768 Kbps.

assumption here that the loss of video fidelity due to compression at data rates lower than 768 Kbps will not affect surgical teleconsultation.[86]

Table 9 presents the total net loadings and utilization rates for channels of various rates if all the requirements listed in table 6, except voice consultations, are included. As seen from table 9, the optimal data rate is 256 Kbps. Again, this choice is possible only if full-motion VTC at this data rate is acceptable for surgical teleconsultation.

Table 9. Total net loading and utilization rate for channels of various data rates and with full-motion VTC requirements

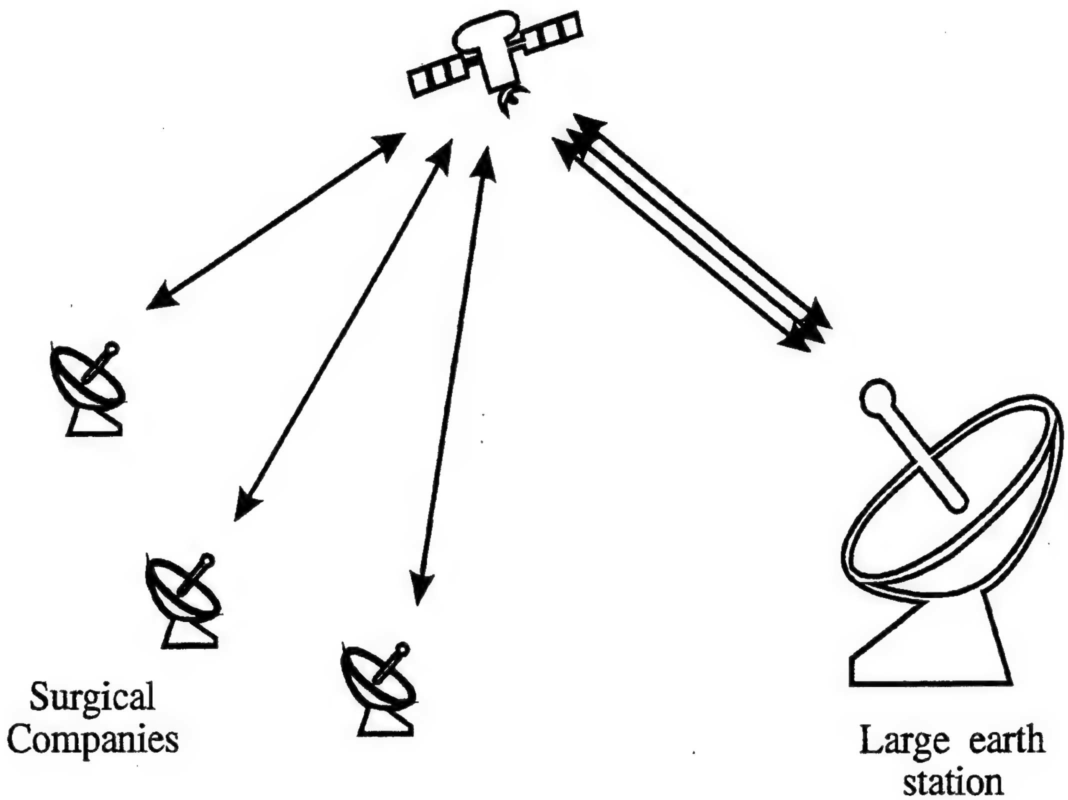
Data rate (Kbps)	Net loading (minute)	Utilization rate (percentage)
128	1,515	105.2
256	848	58.9
384	625	43.4
512	514	35.7
768	403	28.6

Because switched systems aren't available at these data rates (only capable of transmitting up to 64 Kbps), the only means of providing telemedicine with full-motion VTC to the surgical companies would be to equip them with high-capacity dedicated channels. Technically, it is simple to provide a shore-based unit a dedicated point-to-point communication channel with capacity of T1 (1544 Kbps, a standard unit communication capacity) or less. All that is required is the communication equipment (e.g., a parabolic antenna of about 7 to 9 feet in diameter, transceiver), leased use of a satellite communication channel, and leased service of an earth station. The earth station will act as a relay node between the unit and all other users. Figure 13 illustrates the connectivity of this dedicated portion of the network. Since military SATCOM capacity is and will continue to be

86. We assume that full-motion VTC at 768 Kbps is acceptable for surgical teleconsultation. This assumption is necessary because the medical community has not set a standard for VTC for surgical teleconsultation.

insufficient for warfighting uses, high-capacity BLOS medical communications must come from commercial SATCOM.

Figure 13. Potential configuration of high-capacity network



Providing the dedicated communication channel and, hence, telemedicine with full-motion VTC capabilities to the SC has two potential difficulties:

- First, the transportation and logistics support for the communication equipment must be provided. Most of the time this would be relatively simple because the surgical companies are operating as whole units from established locations with infrequent relocations, if any, required after initial setup. But, as mentioned earlier, if they must operate in split-basing mode, then only one-half of the surgical company would have the equipment to support the dedicated channel. The other half of

the surgical company either must operate without this communication support or must have some means of establishing communication with its other half.

- Second, the Medical Battalion would have to compete with the program for procuring the necessary 7-foot antennas for the aircraft carriers, LHA, and LHD. Currently, this is the only existing program for procuring the necessary antennas.[87] However, the mitigating circumstance for this difficulty is that shore-based antennas do not need stabilization equipment and are, therefore, less expensive.[88]

Optimal configuration—If each surgical company requires a dedicated channel, the second issue, configuring the high-capacity portion of the network to realize maximum saving in recurring costs, must be addressed.

Trying to obtain the smallest data rate possible for a dedicated channel may not always provide the expected cost savings. The reason is that going to smaller data rates usually does not yield proportional cost savings. For example, the monthly use charges for dedicated 1544-, 768-, and 384-Kbps channels were $9,548, $6,365, and $5,092, respectively [36]. The best rates are usually available for standard data rates such as T1,[89] E1 (2,048 Kbps, European's equivalent of the T1), or multiples of these rates.

To realize the maximum savings in recurring costs, many small channels can be combined into a larger one. The savings will occur in two places.

87. This program started in FY95 and is expected to last well into the 2005-2015 time frame.

88. Stabilization equipment is needed for shipboard installations to keep the antenna pointing at the satellite in the presence of the ship's rollings and movements.

89. For the Challenge Athena capability (full T1), the annualized recurring cost was $1,476,000 for leasing the channel and $1,020,000 for the use of the earth station and associated land lines.

- First, it is more cost effective to lease one large channel than many smaller ones. For example, installing a T1 channel via land line would incur a fixed cost of $2,038 and monthly recurring cost of $7.25 per mile of connection. Similarly, installing a T3 channel via land line (with 30 times the capacity of a T1) would incur $10,500 and $115 for fixed and recurring costs, respectively [36]. That is, a T3 would cost only 5 times more in fixed costs and 15 times more in recurring costs despite having 30 times more capacity.

- Second, because the reserve capacity (equal to [1 - utilization rate]) of the shared channel does not need to be equal to the sum of the reserve capacities of each channel, the capacity of a shared channel will be less than the sum of the capacities of all individual smaller channels. For example, if the capacity of the dedicated channel given to each surgical company is 768 Kbps, two surgical companies could share a standard size T1 channel (even though 2 x 768 = 1,536 Kbps is 99.5 percent of the T1 capacity, 1,544 Kbps). Even with sharing, two T1 channels must be leased to support the three surgical companies anticipated for medical support of the sustained scenario. On the other hand, if the capacity is lower (for example, 512, 384, or 256 Kbps), all three surgical companies could share a single T1 channel and still have spare capacity that could be shared with other units.[90]

Summary

The following are the main conclusions of this chapter:

- Given the estimated requirements for the communications between the field medical providers and specialists at higher echelons, as shown in table 5, medical functions of the ATF are not likely to receive adequate communication support. The main reason for this will be the lack of equipment and communication channels. The probable solution to this shortfall is the

90. Sharing requires that each surgical company have a complete set of equipment (7- to 9-foot antenna and transceiver).

adaptation of the broadband CDMA technology as well as equipment for military use.

- Conversational, voice, and VTC communication will drive the capacity requirements. Data communications, which are more efficient, can easily be accommodated. An exception to this will be the indiscriminate and unnecessary transmission of high-resolution imageries of X-ray and other teleradiology applications.
- Providing increased medical training as far forward as possible remains the best option to reduce communication requirements and to minimize the deleterious effect of insufficient communication capacity.

Chapter 7: Conclusion and summary

The doctrine governing Marine Corps warfighting in the twenty-first century will be different from current doctrine in several ways, often making it more challenging to provide ground medical support. Under OMFTS, units will be farther from permanent medical facilities, be dispersed more widely, move less predictably at higher speeds, and be more interspersed with enemy. Evacuating casualties will expose personnel to new risks, and there will be longer waits before casualties can be taken to permanent medical facilities.

Given this view of the future, we asked:

- What are Navy medicine's minimum *information requirements* providing medical support in this new combat environment?
- What information and communication systems should be used to handle these new, more difficult circumstances?

To answer these questions, we analyzed a continuum of future scenarios, under three nominal organizational frameworks for medical. These three example organizations—limited, transitional, and sustained—were chosen to illustrate the range of configurations that medical support could take.

We defined two kinds of information: *immediate* knowledge of particulars and *training* knowledge based on instruction, experience, or study. The first type of information is received *during* a crisis in the form of voice, data, image, or video; the second kind is obtained *before* an emergency occurs. Both kinds of information can make decisions quicker and more accurate if it is sufficiently organized and provided to the right people at the right time.

We developed information requirements based on focus groups and interviews with clinical experts, reconstruction of medical exercise

play, and analysis of historical and simulated casualty data. Information requirements can be summarized as supporting three systems:

- Treating and sustaining casualties
- Evacuating, regulating, and tracking casualties
- Obtaining medical supply.

Treatment and sustainment

Training is the most important type of information for treatment because it can be applied immediately, it takes up no space, and it weighs nothing. In addition, to support the onsite treatment decisions, voice and data are sufficient from point of initial injury through the shock trauma platoon; at the surgical company and beyond, image, and possibly video, would also be needed. This additional capability would compensate for the fact that fewer specialists are now at the surgical company. Information should be pulled—the person treating casualties should be able to initiate communications, without getting information requests in the midst of dealing with casualties. Information requests caused by offers of unsolicited consultations would likely interfere with caregivers' ability to handle casualties efficiently.

Evacuation and medical supply

For the other two systems—evacuation and medical supply—sufficient information can be supplied by a data system with voice backup. The proposed evacuation, regulation, and tracking system would provide access to several electronic bulletin boards and a near-real time picture of the overall situation and individual casualty movement status. The proposed supply network would rely on data to give everyone access to an electronic bulletin board that supplies in-transit visibility.

After identifying the general requirements, we considered the costs, feasibility, and technical characteristics of present and likely future communication systems to supply this information:

- Data systems present no problem. Medical information in the form of data can be supplied without taxing system capacities.
- Providing extensive, unlimited voice consultation systems, down to the unit corpsman, would severely strain communication resources.
  - — Some combination of restricting availability of voice consultations and improving training to compensate (i.e., use training to reduce reliance on consults) could be used to minimize this problem. Data systems like e-mail can also minimize the need for voice consults.
- Video capability at the surgical company would be extremely costly—in both data rate and money—and may not be a minimum requirement
  - — Improved teleconsulting can be provided at the surgical company with still image transfer and voice communications at reduced cost.

Achieving successful integration of any information/communication system requires (a) investment in advanced medical training for corpsmen and some or all Marines and (b) a research and development effort for lightweight, easy-to-use medical equipment and treatments. Finally, human nature under stress is to overuse any communication system. To avoid system overload, training will need to emphasize communications discipline. Also, using data capabilities such as e-mail should reduce reliance on voice communications. To avoid having people suffer from information overload, interfaces must be developed to present only relevant data in an organized fashion.

Our findings provide a conceptual basis for future medical information and communication systems. Future experiments should put these and other results to the test. Exercises and wargame efforts, such as CSS Enterprise, *Vanguard '96*, and the Naval Expeditionary Concept of Care (NEC^3) workshop, provide an indispensable process to refine these requirements.

Appendix A: Marine Corps' transportation assets

Table 10. Marine Corps transportation assets: present and future

	Operational speed	Mission radius	Military lift	Casualty load
Helicopters				
CH-46E (Sea Knight)	137 kt	90 n.mi.	18 troops	15 litters+2 med. attendants
V-22 (Osprey)	250 kt	200 n.mi.	24 troops	12 litters+med. attendants
CH-53E (Super Stallion)	170 kt	115 n.mi.	56 troops	N/A
CH-53D (Sea Stallion)	150 kt	270 n.mi.	38 troops	24 litters
UH-1N (Twin Huey)	110 kt	125 n.mi.	13 troops	6 litters+1 med. attendant
Landing Craft				
LCAC (Landing Craft Air-Cushion)	40 kt[a]; 10 mph	100 n.mi.	60-75 tons and 24 troops	[b]
LCU 1600 Class (Utility Landing Craft)	11 kt	600@8 kt	170 tons or 350 troops	N/A
LCM 8 Type (Mechanized Landing Craft)	12 kt	95@9 kt	60 tons or 150 troops	N/A
LCM 6 Type (Mechanized Landing Craft)	9 kt	65 n.mi.	34 tons or 80 troops	N/A
LCPL (Landing Craft Personnel)	20 kt	75 n.mi.	17 troops	N/A
RIB (Rigid Inflatable Boat)	25 kt		15 troops, 1,000 lb	N/A
Amphibious Assault Vehicles				
AAVP-7 (Amphibious Assault Vehicle, Personnel)	6 kt[a]; 30 mph	25 n.mi. 300 miles	18 troops, 10,000 lb	6 litter patients
AAAV (Advanced Amphibious Assault Vehicle)[c]	20 kt[a]; 35 mph		18 troops	N/A
Ground Transport				
M997 HMMWV, Maxi-Ambulance	105 km/h	240 km		4 litter or 8 ambulatory patients

a. Operational speed over water is reported in knots (kt). Operational speed over land is reported in miles per hour (mph).

b. LCAC can carry 24 ambulatory patients in the port and starboard cabins. In addition, the LCAC can accommodate nine M997 (HMMWV) Maxi-ambulance or 2 LVTP-7 (also referred to as AAVP-7). The Personnel Transport Module (PTM) can be installed in less than 4 hours by about 20 people, and can carry 180 troops or 108 litters (6 modules each carry 30 troops or 18 litters). Other temporary shelters, such as the Marine Corps Expeditionary Shelter System (MCESS), may be modified to transport ambulatory or litter casualties.

c. The AAAV Program is in the Demonstration/Validation phase. These specifications reflect Marine Corps requirements for the AAAV.

Table 11. Carrying capacity of amphibious ships

Platform	Helicopter stowage	Helicopters spots	LCAC/LCU
LHA	29 CH-46E equivalents	9	4 LCU 1610 or 1 LCAC
LHD	42 CH-46E equivalents	9	3 LCACs
LSD	None	1, 2[a]	3 LCU or 4 LCAC
LPD	None	2	2 LCACs
LPD-17[b]	4 CH-46E equivalents	N/A	2 LCACs

a. The Anchorage class has 1 helo spot; the Whidbey Island class has 2 helo spots.
b. The LPD-17, previously referred to as the LX, will replace LPD, LSD-36 (Anchorage class), LKA, and LST.

Appendix B: Future information and communication architectures

In this appendix, we present a more detailed overview of the information and communication architectures that we believe are likely to be available to support an Amphibious Task Force in the 2000 to 2015 time frame.[88] This analysis of probable future technologies is the basis for our assumptions regarding the desired communication equipment, computers, and characteristics of the communication architecture that we feel will be both available and capable of supporting ATFs operating under OMFTS, Sea Dragon, or more traditional concepts. These assumptions are laid out in chapter 6, as a necessary step in estimating the medical communication capacity requirements for the future.

Although this study focuses on medical information requirements, we discuss the characteristics of the architectures in the context of the entire ATF and not just its medical functions. We believe this is appropriate because *medical information and communication architectures will be a part of the integrated ATF architectures.* There will be no dedicated medical architectures. We do, however, estimate the communication capacity needed to support medical functions only (in chapter 6). This is also appropriate because we want to estimate what loading medical functions will put on the ATF communication architecture.

Our discussion of the supporting architectures will be in two parts—the information and communication architectures.

88. This is based on our synthesis of (a) the communication architecture required to support the Sea Dragon Concepts as envisioned by the Commandant's Warfighting Lab, (b) extrapolations of current and planned military information infrastructure, and (c) promising communication equipment and capabilities currently in research and development.

Information architecture

The primary purpose of an information architecture is to ensure that information will be made available to all users according to their need-to-know. In the simplest terms, the architecture would consist of the means of extracting, disseminating, and processing information and the network of information processing and storage assets.

The future information architecture needs to fully incorporate the "smart push/user pull" concept being advanced today. In this concept, selected information will be pushed to the users as they specify, and users can retrieve additional information when required. The architecture must have provisions that allow information producers to consistently "advertise" the availability of their information to users. This feature, when designed in conjunction with the artificially intelligent electronic "information agent," will ensure efficient and exhaustive information searches.

ATFs will need to be supported by a global network that is transparent to the user. That is, network users would be able to obtain information via the network without the need to know its internal structures. Transparency is achieved by building intelligence into the network. Intelligent networks know where the information is located, the identities and locations of all users, and, most importantly, how to optimally route the information to the intended receivers or requestors.

Organizationally, the integrated network supporting future ATFs will have three distinct levels:

- At the lowest or unit level, all computers that are collocated at a given site, such as shipboard computers, will be interconnected into one or more Local Area Networks (LANs). These networks allow all internal users to have direct access to information that is available to the network. In many instances, these LANs will be permanent installations. Currently, virtually all major ships and shore-based units already have LANs installed in both garrison and deployed environments.
- At the intermediate or ATF level, all the ships and units of the ATF will be linked together into a network. This network

ensures that information available to or generated by any unit of the ATF will be available to all other units of the ATF on a need-to-know basis. Typically, this network will not be permanent but will be established and disestablished together with the ATF. The ATF-level network will also have connections with the highest level, shore-based national network. This connectivity allows information exchange between the ATF and external information sources and users, such as theater and national commands and agencies. Currently, ATF-level networks connecting ships at sea are not yet standardized or developed. However, several efforts are under way at SPAWAR to solve this deficiency.

- The highest level is the global shore-based network supporting national information infrastructures. This network will be a permanent framework. All theater and national information and users are included in this network. Currently, there are initiatives to build the Defense, Government, and National Information Infrastructures (DII, GII, and NII). These information infrastructures are intended to provide conditioned access to all U.S. and selected foreign information providers and users. The Defense Information System Agency is being charged with building the global Defense Information System Network to support the DII.

Currently, many of these separate networks (or parts of them) exist. However, they use different network protocols to govern the ways their users exchange information. Combining these networks requires considerable efforts and cumbersome ad hoc solutions to resolve protocol interoperability issues. In the future, these interoperability issues must be resolved a priori so that these networks can be integrated into a seamless and scalable ATF network at will.

Because the ATF networks can be used in time of war, their components may be degraded, damaged, or disrupted both unintentionally and intentionally. The ATF networks must be robust to prevent these localized problems from disrupting the entire network. Robustness is normally achieved by building hardened and redundant components. Also, the networks must have the capability to detect failures

automatically and the intelligence to self-reconfigure to work around problem areas.

Communication architecture

The primary purpose of the communication architecture is to ensure that every unit within the ATF will have connectivity with all other units. The communication architecture provides the means to establish the connectivity. The information architecture provides the rules governing the use of this connectivity.

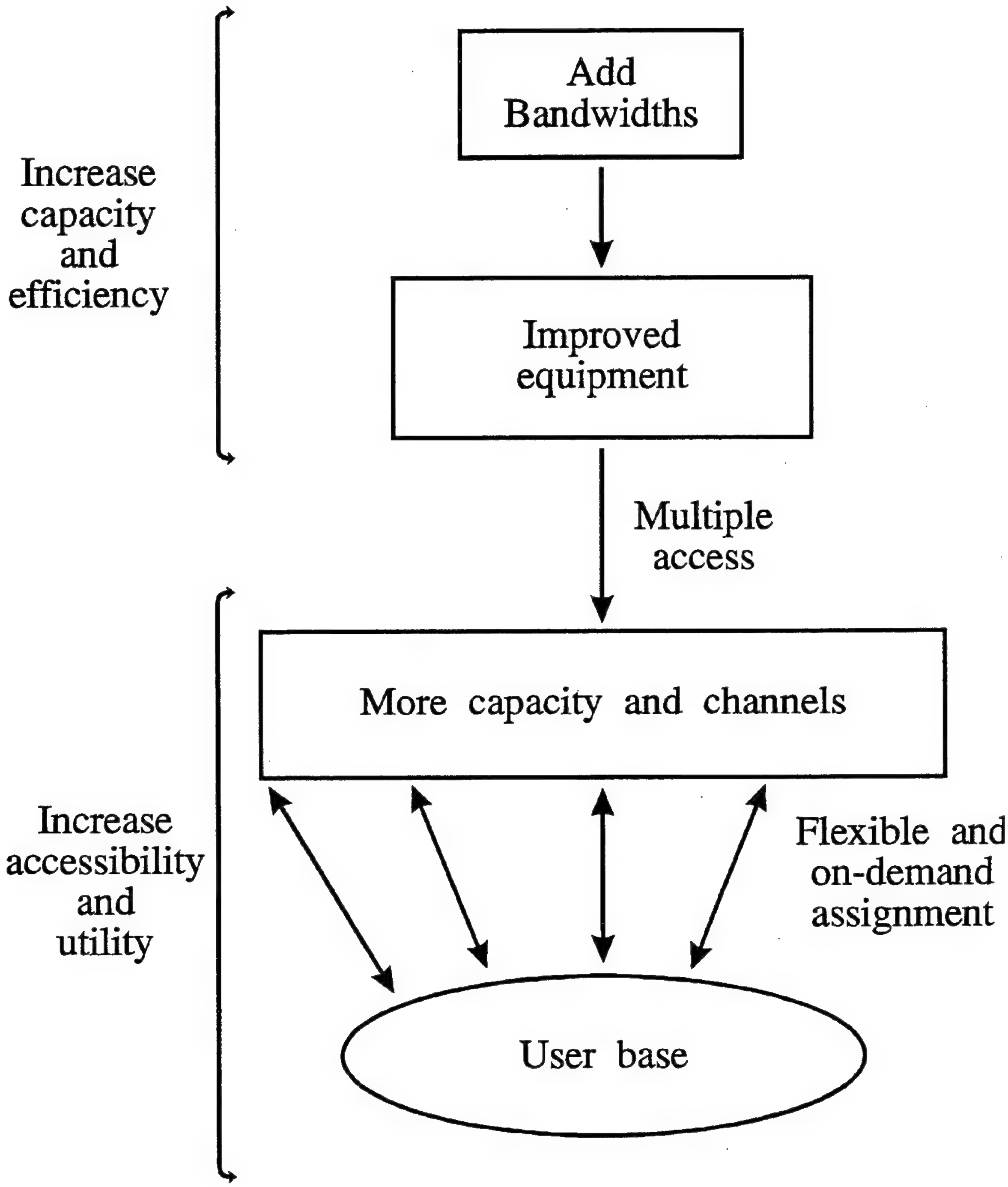
At present and for the foreseeable future, the demand for information is ever increasing. The communication architecture of today cannot keep up with the operational demands for more information. There are two reasons for this shortfall:

- There are inadequate communication bandwidths available at the frequency bands currently in use.
- More importantly, the available bandwidths are being used too rigidly and inefficiently.

To satisfy future demands for information, the communication architectures of future ATFs must (1) have more capacity and use it efficiently and (2) provide greater accessibility and utility to larger user bases.

We will discuss the efforts necessary to achieve these two basic characteristics of future architectures in more detail. The processes of achieving these characteristics are outlined in figure 14, and our discussion will follow the general flow of that chart.

Figure 14. Process of achieving enhanced future characteristics for ATF's communication architecture



Increase capacity and efficiency

There are two ways to increase the capacity of the communication architectures of future ATFs:

- Adding more communication bandwidths
- Making improvements to current and planned equipment to increase their efficiency in converting bandwidths to capacity.

Optimally, both of these efforts must be addressed simultaneously.

Adding communication bandwidths

For sea-based forces, including the ATFs, the most efficient means of adding communication bandwidths will be using higher frequency bands that are currently underutilized or unused. This is so because these forces will continue to rely on satellites to provide high-capacity BLOS communications. Higher frequency bands have considerably higher allocated bandwidths than lower frequency bands. Therefore, there is more capacity to be gained in using higher frequency bands.

For military frequencies, the bandwidth allocations are 100, 500, and 2,000 MHz at UHF, SHF, and EHF, respectively. Thus, available capacity at EHF is four times the capacity at SHF. For commercial SATCOM, the allocated bandwidths are 500 and 1,000 MHz at C/Ku and Ka frequency bands, respectively. The DOD will add the Medium Data Rate (MDR) capability to MILSTAR starting with MILSTAR II. This will provide them with high-capacity EHF communications [37]. In addition, the Navy is installing commercial SATCOM at C/Ku bands to its fleet flagships and aircraft carriers. Several studies commissioned by the Navy have been recommending the use of communication services at Ka frequency band when they are available [14, 32, 38].

Improving efficiency of equipment

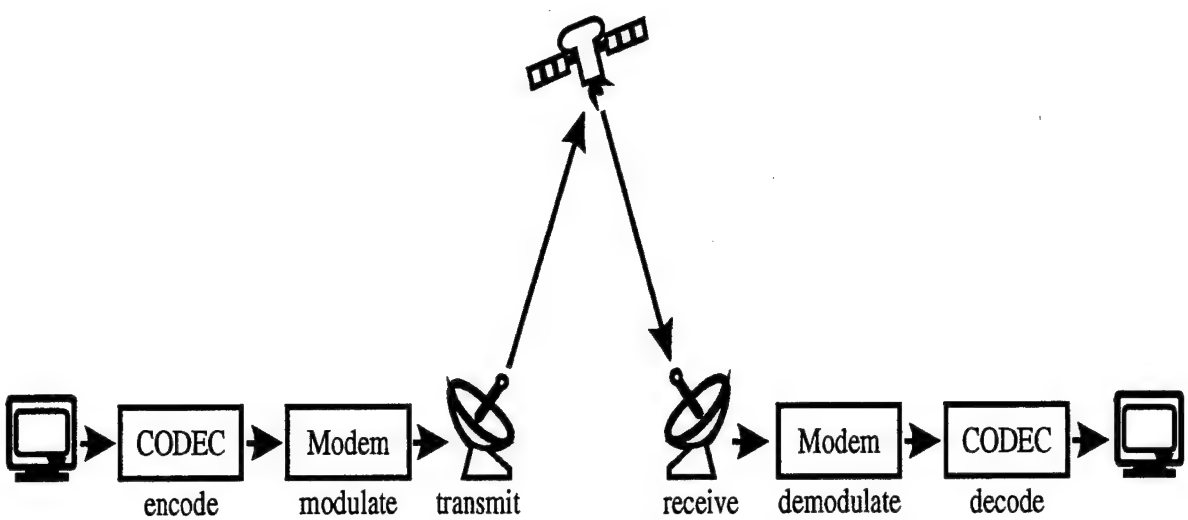
It is not efficient to just add more communication bandwidths. The efficiency of the communication equipment must also be improved. Efficient equipment provides higher capacity for a given amount of bandwidths.

The largest efficiency gains will likely be achieved by making improvements in the following equipment:

- Earth terminal antennas
- Modems[89]
- Coder/Decoders (CODECs).[90]

Figure 15 illustrates the use of this equipment in a transmission of a video picture via a satellite circuit. We will now discuss in more detail the probable improvements that can be made on this equipment.

Figure 15. The use of antennas, modems, and CODECs in a transmission of a video picture via a satellite circuit



89. In layman's terms, *modem*, which stands for modulator/demodulator, is the equipment that modulates or inserts the information to be transmitted onto the communication channels. At the receiver, the modem demodulates the received signal to extract the information.

90. CODEC is the equipment that converts information from user-formats to other formats suitable for transmissions (coding) and vice versa (decoding). For example, CODECs are used to convert a caller's voice to digital information to be passed over the phone. CODECs are also used in VTC to convert video to appropriate transmission formats.

Antenna. Single-band parabolic antennas of today will be replaced with multiband phased-array antennas. The latter antennas typically have higher gains and pointing accuracy than parabolic antennas. This results in the ability to transfer information at higher data rates if other factors, such as power output, remain the same. Multiband capability allows one antenna to cover more than one frequency band. This, in turn, allows added communication channels for a given number of antennas.

Currently, the Navy is engaging in research and development of the multimode multibeam phased-array antennas (MMBA) for shipboard installations [39]. The MMBA antenna is designed to operate in both military X-band and commercial C-band. The Boeing Defense and Space Group is also developing a family of small, low-cost and multibeam phased-array antennas for mounting on aircraft and vehicles. These antennas can operate in military SHF and EHF bands and commercial Ku and Ka bands [40].

Modems. Modems will use advanced digital modulation techniques together with forward error correction (FEC). Advanced modulation techniques can increase the capacity of a communication channel at least by a factor of two. However, they are more susceptible to transmission errors. To allow the receivers to correct these errors, FEC bits are added to the transmitted data—at the expense of capacity. For circuits with relatively high error rates, such as satellite communications, FEC is preferable to traditional methods of error correction, because it costs less in terms of capacity.

Many of today's military modems are using modulation techniques known as Binary or Quaternary Phase Shift Keying with a modulation rate of about 1 bit per Hz. Thus, a 25-KHz channel would have a nominal data rate of 25 Kbps. More advanced techniques, such as Quadrature Amplitude Modulations (QAM), are currently available. These techniques, which are capable of providing modulation rates of multiple bits per Hz, are already in use in commercial SATCOM.

Today, the widely used method of error correction is retransmission for those messages with errors. This method also requires adding bits to the transmitted data to *detect* errors. The costs of the retransmission method depends on the error rates of the communication channels.

They can vary from a few to 100 percent (complete shutdown of the channel). In contrast, the costs of FEC are fixed between 7 and 50 percent of the capacity. Variations of Trellis coding have been used with QAMs to correct transmission errors. The use of constant envelope, 8-phase, Trellis-coded modulation to improve MILSATCOM channel capacity has been recommended by the Space Panel of the Naval Studies Board to the Navy [38].

CODEC. CODECs that rely on adaptive, statistical-based algorithms to reduce the capacity necessary to code information will be widely used. Examples of such CODECs are those that use the Adaptive Differential Pulse Code Modulation (ADPCM) algorithm to code voice for transmission at data rates as low as 4.8 Kbps with small sacrifices in quality. Other examples are CODECs that are being developed for ITU H.261 standards for full-motion VTC at data rates as low as 64 Kbps.

Increase accessibility and utility

After obtaining the additional capacities, the communication architectures must make them accessible and useful to the users. In the future, with increased demands for information from even the smallest units, the architectures must provide this accessibility and utility to greater numbers of users. To do this, communication architectures of future ATFs must have the following:

- Efficient means of providing multiple access
- Flexible means to provide on-demand access
- Security

We now discuss these characteristics in more detail.

Efficient means to provide multiple access

The architectures must employ efficient multiple-access schemes to provide a greater number of communication channels. These channels will, in turn, provide increased access to communications for all units, including individual teams and corpsmen.

Multiple access is the process that allows multiple users to share one communication circuit. Each user is assigned a channel within the overall circuit. The channels can be separated from each other by keeping distinct either their frequency, the time when they access the link, or the code they use to modulate their signal. These are referred to as frequency, time, and code division multiple access (FDMA, TDMA, and CDMA). With *FDMA*, each channel is assigned a portion of the circuit's bandwidth. FDMA is simple to implement—with simple terrestrial equipment—but it uses a circuit's capacity least efficiently. With *TDMA*, each channel uses the full bandwidth of the circuit but only during its allocated time. This requires complex and precise time control. Finally, with *CDMA*, each channel can use the entire circuit all the time, but each uses a different random code to modulate its signal. Without the proper code, a channel cannot decode the signal of another channel, even if both are in use at the same time. CDMA requires complex signal processing techniques but promises the greatest level of simultaneous access to the circuit.

At the high-capacity end, the trend is to use TDMA to let many channels share one FDMA circuit. This hybrid TDMA/FDMA scheme provides optimal balance between FDMA's simplicity and TDMA's efficiency. At the low-capacity end, CDMA promises to be the most efficient multiple-access scheme.

A military application of the hybrid TDMA/FDMA multiple-access scheme is the use of the 5- and 25-KHz DAMA standards for UHF MILSATCOM. The allocated bandwidth at UHF frequency band has been divided into 5- and 25-KHz channels. Currently, these channels are typically assigned to a particular use, such as voice command nets. There are not enough channels to support current demands. The DAMA standards will allow up to 15 subchannels sharing one of these 5- or 25-KHz channels using TDMA. Each subchannel can then be assigned to a particular use instead of the full channel. This results in a 15-fold increase in the number of UHF channels available for communications. A similar example of a hybrid TDMA/FDMA scheme from commercial industry is the Very Small Aperture Terminals program.

The following example compares the capabilities of FDMA, TDMA, and CDMA in providing multiple access. Each cell of the current cellular systems has an allocated bandwidth of about 1.8 MHz, which is divided into sixty 30-KHz channels using FDMA. Fifty-five of these channels can be used to service calls simultaneously. With the new digital standard, IS-54, which uses TDMA to share one 30-KHz channel, the number of simultaneous calls increases from 55 to 165 (with 660 as the theoretical maximum) per cell. For the same constraints, CDMA can theoretically support 1,270 users simultaneously [33]. For this capability, the wireless communication industry has adopted a CDMA scheme proposed by Qualcomm as its standard (IS-95).

Flexible schemes to provide on-demand access

Now that its capacity has been divided into a great number of communication channels, the architecture must be able to efficiently assign these channels to users. Currently, communication architectures assign their channels to specific functions on a permanent basis. Even if a channel is idle, its capacity cannot be temporarily used to satisfy other requirements. These architectures are commonly referred to as the "stovepipe" architecture. On the other hand, future communications architecture must be able to provide on-demand access for all of its channels. The architecture will assign channels to users only for as long as necessary. Once the calls have been terminated, the channels will be ready to be assigned to other users for other uses. Further, the communication channels must not be allocated fixed capacities based on some predetermined criteria. Rather, the architecture must be able to allocate the needed capacities to channels on a per-call basis.

Fortunately, there are efforts to move away from the stovepipe architecture to the flexible and dynamic architecture described here. Examples of these efforts are the new UHF DAMA standards and, more importantly, the Communication Support System. This system provides central controls of all shipboard communication systems. It will determine and allocate capacity and equipment for each use only as necessary. It will enable the operator to concentrate on the substance of communications and not on the forms of communications.

Enhanced security to increase utility of the system

Finally, the operational concepts that would be employed in the limited and transitional scenarios call for additional secured communications capabilities for all units. This is especially true for individual teams, unit corpsmen, and casualties operating under the Sea Dragon concepts. Enhanced security of the communications architecture would certainly increase the utility of the communication systems to these users.

Secured communication capabilities, as used here, include not just the means to ensure safe and accurate delivery of information to the intended recipients while denying the same to the unintended receivers, but also the means to provide the ability to communicate at will without fear of detection or interception by enemy forces. That is, the architectures must use communication means not only with low probability of exploitation (LPE) features but also with low probability of detection (LPD) and intercept (LPI).[91] Current communication architectures have excellent LPE features, such as secured and survivable communication channels employing robust and diverse encryption devices and antijam techniques. However, except for special covert operations, there is insufficient emphasis on the LPD and LPI features in normal operations. For future operations requiring many small teams to operate interpersed with the enemy, LPD and LPI communications will be required to prevent compromising the safety of the teams.

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91. LPD denies the unintended receiver the ability to *detect* the signals. Triangulation to obtain position of the transmitter, which is a major concern of medical providers regarding protection of casualties, requires detection of the signals. If an unintended receiver detects the signal, LPI denies it the ability to distinguish one signal from others (i.e., to *intercept* the signal). Finally, if the signal is intercepted by an unintended receiver, LPE denies it the ability to exploit the signal to obtain useful information, such as sender's identity, message content, and so on.

For these teams, the CDMA multiple-access schemes, which use *direct sequence* codes, are of great interest because they provide communications with inherent antijamming, LPD, and LPI features. Direct sequence (DS) is a spread spectrum[92] (SS) technique. DS spreads the signal over a bandwidth many times the bandwidth required to convey the information. A *pseudorandom* code is used for the spreading. As a result of spreading, the transmitted power per unit of bandwidth is reduced to below the background noise level. At reception, a receiver with the spreading code would be able to coherently add the received signal to raise the wanted signal out of background noise. On the other hand, a receiver without the spreading code cannot do the same and, thus, cannot distinguish or extract the signal from the background noise. Both the signal and the background noise are mixed together and appear random to the receiver. If a receiver cannot detect the signal, it can neither triangulate nor in any other way exploit the communication.

Further, noise jamming would appear to the receiver as additional noise, which can be overcome by coherently adding the signal over time. More sophisticated jamming techniques require knowledge of at least some features of the signal. LPD, LPI, and LPE make these features hard to detect and acquire by unintended receivers. This is the antijamming feature of DS/SS.

Summary

In this appendix, we present a list of the characteristics of the information and communication architectures we believe to be necessary to support future ATFs. These ATFs can operate in a continuum of operations ranging from the limited scenario through the transitional to the sustained scenarios. This list is not exhaustive, but it does describe the salient characteristics.

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92. Spread spectrum is a radio communication and radar technique that spreads a signal bandwidth over a much wider bandwidth for transmission and despreads the received signal to the original bandwidth at reception. This technique has been used in the military to provide secured communications.

Appendix C: Prepared questions for west and east coast focus groups

Questions for west coast focus groups

1. Introduction to the future battlefield and how it might affect medical support.
2. As a medical provider, what are YOUR views of the strengths and weaknesses of the current combat casualty management system for dealing with the future battlefield?
3. How could medical support the warfighters, given the possible future concept of operations?
   a. Modifying the current configuration of medical combat support?
   b. Starting a medical combat support configuration from scratch?
4. What types of information are needed, by who, at what times, in these configurations?
5. Any other thoughts about the future battlefield, and about future medical support?
   a. In your role as ——, what would you need to deal with the future battlefield?
6. Who else should we talk to about these topics?

Questions for east coast focus groups

Treat/diagnose/assess/maintain/sustain

1. Are there ways that information could help the (corpsman, you) fulfill this function in each of the three scenarios? (Decide/implement; information in/out)
2. Please give examples of what/when information would be useful to help the corpsman fulfill this function.
3. Who, where?
4. What form should the information be in? (How: voice, data, image, video?)
5. We have heard that the following conditions are ones in which a corpsman might want to consult with a physician to make a decision. Are there others? For these decisions, what information would be most useful?
   a. Cardiac tamponade; internal bleeding(?)
   b. Remove a limb/tourniquet; broken bone(?)
   c. Move casualty or not?
   d. Pneumothorax (are data and voice enough?)
   e. Drug administration—e.g., give a second shot of morphine?
   f. Disease diagnosis—malaria, pneumonia, or flu?
   g. Prevention

Evacuate/move

1. Are there ways that information could help (you/the corpsman) fulfill this function in each of the three scenarios? (Decide/implement; information in/out)
2. Please give examples of what information would be useful to help you/the corpsman fulfill this function.

3. What form should the information be in (voice, data, image, video)? Should this information be programmed into a personal status monitor (PSM)?)
4. What do you think of the field card?
5. How would you feel about a voice-recognition tool that records:
   a. Whether a CBR casualty
   b. Casualty id (name, id number)
   c. Whether gave morphine, other drug
   d. Whether used a tourniquet
   e. Where is the wound?

Appendix D: Information for regulating and tracking

In this appendix, we provide a table that shows the information/communication requirements for regulating and tracking casualties in the *sustained scenario,* up to but not including the PCRTS.[93] The table shows the required information/communication in the rows (e.g., casualty name) and communication nodes (e.g., HM) in the columns. For each cell, we use the following symbols:

- "D" stands for low-rate data, such as text or numbers in an electronic bulletin board that appropriate persons can access.
- "V" stands for voice communication.
- "Tr" stands for training.

Each cell lists the system, or systems, required to support the particular information and communication requirements for each node. The systems are listed in order of priority. The first would be considered the primary system. For example, in the table, the "D" in the first row means that the casualty name, rank, SSN, nation, and status are primarily kept on the electronic bulletin board. If another system is listed in the cell, it is either a secondary system or a backup system.

A secondary system is one that might become the primary system at certain times. It is listed second. For example, the "V" for "Chem/bio hazard" is considered a secondary system because there might be times when voice, rather than data, becomes the preferred primary form of communication to deliver that information. Using voice to tell people that a group of casualties are chem/bio hazards allows

93. We are looking at a system that would support the movement, regulation, and tracking of casualties from the unit corpsman, through the BAS, STP, surgical company, up to the PCRTS.

those who send a message to ask receivers to confirm that the message was, indeed, heard.

A backup system is denoted by parentheses. Any system in parentheses is to be used when the primary system fails or when there is a question about the truth of data in the system. For example, the "(V)" on the first row means that voice is a backup system for when the data system is down or needs to be questioned.

We use **bold** type to signify that the node represented by that cell can both input and access that particular information from the system. Otherwise, we assume the node primarily reads from the system (we do not assume input capability is denied these nodes). For example, the first bold "**D,(V)**" under HM means that a unit corpsman might be the one to input casualty name, rank, SSN, nation, and status to the bulletin board (or initiate the voice call if using the back-up system). Looking across that row, you can see other cells are not bold type, meaning that, for example, the unit commanders, ATF Headquarters, and Ground transport command will not be inputting those pieces of data for that row; rather, they will primarily access those data as necessary for their use.

Table 12. Information matrix for regulating and tracking

	Treatment nodes		Command Headquarters			Evacuators (transportation commands)			Regulator
Information	HM	BAS, STP, surgical co., PCRTS, etc.	Unit[a]	ATF[b]	JTF[c]	Ground	Air	Surface	MRCO
Casualty name, rank, SSN, nation, status	**D,(V)**	D,(V)	D,(V)	D,(V)	D,(V)	D,(V)	D,(V)	D,(V)	D,(V)
Unit of casualty	**D,(V)**	D,(V)	D,(V)	D,(V)	D,(V)	D,(V)	D,(V)	D,(V)	D,(V)
Specialty	**D,(V)**	D,(V)	D,(V)	D,(V)	D,(V)	-	-	-	D,(V)
Location, radio freq., call sign, no. patients there	**D,(V)**		D,(V)	D,(V)	D,(V)	D,(V)	D,(V)	D,(V)	D,(V)
How soon must be evacuated	**D,(V)**	**D,(V)**	D,(V)	D,(V)	D,(V)	D,(V)	D,(V)	D,(V)	D,(V)
Diagnosis	**D,(V)**	**D,(V)**	D,(V)	D,(V)	D,(V)	-	-	-	D,(V)
When ready to be evacuated	**D,(V)**	**D,(V)**	D,(V)	D,(V)	D,(V)	D,(V)	D,(V)	D,(V)	D,(V)
Chem/bio hazard? Type?	**D,V**	**D,V**	D,V	D,(V)	D,(V)	D,V	D,V	D,(V)	D,(V)
How to handle hazard	**TR,V**	**D,V**	-	-	-	D,V	D,V	D,V	D,V
Psychiatric/safety hazard?	**D,(V)**	**D,V**	-	-	-	D,V	D,V	D,V	D,V
How to handle hazard	**TR,V**	**D,V**	-	-	-	D,V	D,V	D,V	D,V
Number of casualties	**D,(V)**	**D,(V)**	D,(V)	D,(V)	D,(V)	-	-	-	D,(V)
Casualty return to duty? (Y/N)	**D,(V)**	**D,(V)**	D,(V)	-	-	-	-	-	D,(V)
When will return?	**D,(V)**	**D,(V)**	D,(V)	-	-	-	-	-	D,(V)
Casualty has died (Y/N)	**D,(V)**	**D,(V)**	D,(V)	D,(V)	D,(V)	-	-	-	D,(V)
Time, date of death	**D,(V)**	**D,(V)**	D,(V)	D,(V)	D,(V)	-	-	-	D,(V)
Where casualty is going	D,(V)	D,(V)	D,(V)	D,(V)	D,(V)	D,V	D,V	D,V	**D,(V)**
When, how casualty to be evacuated	D,(V)	D,(V)	D,(V)	D,(V)	D,(V)	D,V	D,V	D,V	**D,(V)**

Table 12. Information matrix for regulating and tracking (continued)

	Treatment nodes		Command Headquarters			Evacuators (transportation commands)			Regulator
Information	HM	BAS, STP, surgical co., PCRTS, etc.	Unit[a]	ATF[b]	JTF[c]	Ground	Air	Surface	MRCO
MRCO status board[d]	-	D,(V)	D,(V)	D,(V)	D,(V)	-	-	-	**D,(V)**
Operating beds	-	**D,(V)**	-	-	-	-	-	-	D,(V)
Beds occupied	-	**D,(V)**	-	-	-	-	-	-	D,(V)
Major OR, minor ORs	-	**D,(V)**	-	-	-	-	-	-	D,(V)
Backlog in ORs--pts.	-	**D,(V)**	-	-	-	-	-	-	D,(V)
Backlog in ORs--hrs.	-	**D,(V)**	-	-	-	-	-	-	D,(V)
Patients lateral transfer	-	**D,(V)**	-	-	-	-	-	-	D,(V)
Patients evac out of AOA	-	D,(V)	-	-	-	-	-	-	**D,(V)**
Blood status (units by type)	-	**D,(V)**	-	-	-	-	-	-	D,(V)
No. units required, by type	-	**D,(V)**	-	-	-	-	-	-	D,(V)
Delivery date, destination	-	**D,(V)**	-	-	-	-	-	-	D,(V)
Number dedicated OR	-	**D,(V)**	-	-	-	-	-	-	D,(V)
Number of other OR	-	**D,(V)**	-	-	-	-	-	-	D,(V)
No. of fixed x-ray	-	**D,(V)**	-	-	-	-	-	-	D,(V)
No. of portable x-rays	-	**D,(V)**	-	-	-	-	-	-	D,(V)
No. of ICU beds	-	**D,(V)**	-	-	-	-	-	-	D,(V)
No. of other sickbay beds	-	**D,(V)**	-	-	-	-	-	-	D,(V)
Overflow beds	-	**D,(V)**	-	-	-	-	-	-	D,(V)
Medical officers, by NOBC	-	**D,(V)**	-	-	-	-	-	-	D,(V)

a. Includes unit commander, S-1 and S-4 Officers.
b. Includes CATF/CLF; CATF/CLF Surgeon; and S-1,S-2,and S-4 Officers.
c. Includes CJTF, J-1, J-2, J-4, NBC Officer, JTF Surgeon, Preventive Medicine Officer, and Environmental Medicine Officer.
d. All relevant pieces of information are input by the individual MTFs. These data are organized, updated, and maintained on the electronic status board, which is ultimately controlled by the medical regulating officer, but available with read access to all other nodes.

Appendix E: Information for medical supply

In this appendix, we provide a table that shows the information/communication requirements needed for field medical supply in the *sustained scenario.*[94] The table shows the required information/communication in the rows (e.g., casualty name) and communication nodes (e.g., HM) in the columns. For each cell, we use the following symbols:

- "D" stands for low-rate data, such as text or numbers in an electronic bulletin board that appropriate persons can access.
- "V" stands for voice communication.

Each cell lists the system required to support the particular information and communication requirements for each node. For the medical supply, we found data to be the preferred information and communication system to support medical supply in the field. This system should have a voice backup to be used when the primary system fails or when there is a question about the truth of data in the system. Voice is represented by (V) to indicate its backup status for the supply function.

We use **bold** type to signify that the node represented by that cell can both input and access that particular information from the system. Otherwise, we assume the node primarily reads from the system (we do not assume input capability is denied these nodes). For example, the first bold "**D,(V)**" under BAS and STP means that a BAS or STP might be the one to input the name of the unit ordering supplies into the bulletin board. Looking across that row, you can see other cells are not in bold type, meaning that, for example, the FSSG/SMU,

94. By *field medical supply* we mean the supply and resupply of the unit corpsman, BAS, STP, and surgical company. We do not include supplies for field hospitals or other in-theater medical assets (TA-H, or PCRTS).

MEDBN S-4, and Medical Logistics Company will not be inputting those pieces of data for that row; rather, they will primarily access those data as necessary.

Table 13. Information matrix for medical resupply

Information	HM[a]	BAS	Unit S-4	STP	Surgical Company (incl S-4)	Surgical Co. S-4	MEDBN S-4	FSSG/ SMU	Medical Logistics Co.	Logistics Co.	MCSSD
Name of unit ordering supply	-	**D,(V)**	D,(V)	**D,(V)**	**D,(V)**	D,(V)	D,(V)	D,(V)	D,(V)	D,(V)	D,(V)
Location of unit ordering supply	-	**D,(V)**	D,(V)	**D,(V)**	**D,(V)**	D,(V)	D,(V)	D,(V)	D,(V)	D,(V)	D,(V)
AMAL no.	-	**D,(V)**	D,(V)	**D,(V)**	**D,(V)**	D,(V)	D,(V)	D,(V)	D,(V)	D,(V)	D,(V)
AMAL name	-	**D,(V)**	D,(V)	**D,(V)**	**D,(V)**	D,(V)	D,(V)	D,(V)	D,(V)	D,(V)	D,(V)
Line item no./name	-	**D,(V)**	D,(V)	**D,(V)**	**D,(V)**	D,(V)	D,(V)	D,(V)	D,(V)	D,(V)	D,(V)
Quantity ordered	-	**D,(V)**	D,(V)	**D,(V)**	**D,(V)**	D,(V)	D,(V)	D,(V)	D,(V)	D,(V)	D,(V)
Date ordered	-	**D,(V)**	D,(V)	**D,(V)**	**D,(V)**	D,(V)	D,(V)	D,(V)	D,(V)	D,(V)	D,(V)
Priority of order	-	**D,(V)**	D,(V)	**D,(V)**	**D,(V)**	D,(V)	D,(V)	D,(V)	D,(V)	D,(V)	D,(V)
Name and phone of POC for ordering unit	-	**D,(V)**	D,(V)	**D,(V)**	**D,(V)**	D,(V)	D,(V)	D,(V)	D,(V)	D,(V)	D,(V)
Approximate delivery date wanted	-	**D,(V)**	D,(V)	**D,(V)**	**D,(V)**	D,(V)	D,(V)	D,(V)	D,(V)	D,(V)	D,(V)
Logistics confirmation order received	-	D,(V)	D,(V)	D,(V)	D,(V)	D,(V)	D,(V)	D,(V)	**D,(V)**	**D,(V)**	D,(V)
Ability to fill order	-	D,(V)	D,(V)	D,(V)	D,(V)	D,(V)	D,(V)	D,(V)	**D,(V)**	**D,(V)**	D,(V)
Approx. delivery date/time to logistic officer	-	D,(V)	D,(V)	D,(V)	D,(V)	D,(V)	D,(V)	D,(V)	D,(V)	D,(V)	**D,(V)**
Receipt of delivery to logistic officer	-	D,(V)	**D,(V)**	D,(V)	D,(V)	**D,(V)**	**D,(V)**	D,(V)	D,(V)	D,(V)	**D,(V)**
Approx. delivery date/time (to MTF)	-	D,(V)	**D,(V)**	D,(V)	D,(V)	**D,(V)**	**D,(V)**	D,(V)	D,(V)	D,(V)	D,(V)

a. In the sustained configuration, the unit corpsman gets his supplies from the BAS. The BAS then orders additional supplies as required to support the station and the unit corpsman.

Appendix F: Information for medical treatment

In this appendix, we provide a table that shows the information/communication requirements needed to support the treatment of casualties in the *sustained scenario,* up to but not including the PCRTS.[95] The table shows the types of treatment decisions being supported in the rows (e.g., Do we need immunizations?) and communication nodes (e.g., HM) in the columns. For each cell, we use the following symbols:

- "D" stands for low-rate data, such as text or numbers in an electronic bulletin board that appropriate persons can access.
- "V" stands for voice communication.
- "Tr" stands for training.

Each cell lists the system, or systems, required to support the particular information and communication requirements for each node. The systems are listed in order of priority. The first would be considered the primary system. For example, in the table, the "D" in the first row means that whether we need immunizations is primarily kept on the electronic bulletin board, not passed by voice. If another system is listed in the cell, it is either a secondary system or a backup system.

A secondary system is one that might become the primary system at certain times. For example, while training—"TR"—is considered to be the primary information required for the unit corpsman (HM) to perform initial contact treatment, a voice communication system may become the preferred primary system when training is inadequate to meet the specific need of a particular casualty. The "V"s in the initial

95. We are looking at an information/communication system that would support the treatment of casualties by the unit corpsman, at the site of injury, and health care providers at the BAS, STP, and surgical company.

contact and HM cells reflect this secondary preference for voice as compared to training.

A backup system is denoted by parentheses. Any system in parentheses is to be used when the primary system fails or when there is a question about the truth of data in the system. For example, the "(V)" for all examples of treatment information means that voice should be provided as backup system for when the data system is down or needs to be questioned.

We use **bold** type to signify that the node represented by that cell can both input and access that particular information from the system. Otherwise, we assume the node primarily reads from the system (we do not assume input capability is denied these nodes). For example, the bold "**D,(V)**" in the treatment information and HM cells means that the unit corpsman (HM) will input any information regarding the treatment he provided a casualty. Looking across those rows, you can see other cells. For example, the tourniquet treatment and BAS, STP, and surgical company cells are not in bold type. That is because, in this case, we assume that the tourniquet would be applied at the site of injury, and subsequent treaters will need to access that information, as opposed to inputting it into the system.

Table 14. Information matrix for treatment and consultation

Functions: (summary of basic system) Examples of decisions or procedures	Buddy	HM	BAS	STP	Surg. Co.	PCRTS	Unit commands	Transport commands
Prevention: (Data w/ voice secondary)								
Do we need immunizations? Which are needed?[a,b]	-	D,V	D,V	D,V	D,V	D,V	D,(V)	-
What environmental and safety threats are there? How can we prevent illnesses, injuries?[a,b]	-	D,V	D,V	D,V	D,V	D,V	D,(V)	-
Cases of chem/bio/infectious casualties? Where, when?[c]	-	**D,V**	**D,V**	**D,V**	**D,V**	**D,V**	D,V	-
Are troops following prevention procedures?	-	**D,V**	**D,V**	**D,V**	**D,V**	**D,V**	D,(V)	-
Initial contact: (Training w/ voice secondary)								
Is casualty a chemical/biological hazard (Y/N)[d]	**TR,V**	**TR,V**	TR	TR	TR	TR	-	-
If yes, what type of hazard? Appropriate action?[d]	**TR,V**	**TR,V**	TR	TR	TR	TR	-	-
Danger to self or others? (Y/N) What action?[e]	**TR,V**	**TR,V**	TR	TR	TR	TR	-	-
Initial triage: (Training w/ voice secondary)								
Should this casualty be returned to duty?[d]	-	**TR,V**	**TR,V**	**TR,V**	TR	TR	-	-
What priority should casualty have?[d]	-	**TR,V**	**TR,V**	**TR,V**	TR	TR	-	-
Treatment information: (Data w/ voice secondary)								
When was tourniquet put on?[a]	**D,(V)**	**D,(V)**	D,(V)	D,(V)	D,(V)	D,(V)	-	-
What if any drugs were administered?[a]	**D,(V)**	**D,(V)**	**D,(V)**	**D,(V)**	**D,(V)**	**D,(V)**	-	-
If drugs, how much and when?[a]	**D,(V)**	**D,(V)**	**D,(V)**	**D,(V)**	**D,(V)**	**D,(V)**	-	-
Medical history: (Data w/ voice secondary)								
Drug allergies? (Y/N) If yes, what kind?[a]	-	D,V	D,V	D,V	D,V	D,V	-	-
Blood type?[a]	-	D,V	D,V	D,V	D,V	D,V	-	-

Table 14. Information matrix for treatment and consultation (continued)

Functions: (summary of basic system) Examples of decisions or procedures	Buddy	HM	BAS	STP	Surg. Co.	PCRTS	Unit commands	Transport commands
Other useful information? (e.g. diabetes?)[a]	-	D,V	D,V	D,V	D,V	D,V	-	-
Consult, diagnose: (Training w/ voice secondary)								
What are the critical symptoms?[d]	-	**TR,V**	**TR,V**	**TR,V**	**TR,V**	**TR,V**	-	-
How should symptoms be interpreted?[d]	-	**TR,V**	**TR,V**	**TR,V**	**TR,V**	**TR,V**	-	-
How did injury or illness occur?[d]	-	**TR,V**	**TR,V**	**TR,V**	**TR,V**	**TR,V**	-	-
Treat: (Training w/ voice secondary)								
Tourniquet management[d]	-	**TR,V**	TR,V	TR,V	TR,V	TR,V	-	-
Cricothyroidotomy, needle thoracotomy[d]	-	**TR,V**	TR,V	TR,V	TR,V	TR,V	-	-
Prescribe and administer antibiotics[d]	-	**TR,V**	TR,V	TR,V	TR,V	TR,V	-	-
Stabilization surgery[d]	-	-	**TR,V**	**TR,V**	TR,V	TR,V	-	-
Definitive surgery[d]	-	-	-	-	-	**TR,V**	-	-
Dispensation: (Training w/ voice secondary)								
Evacuate? If yes, what priority for evac?[d]	-	**TR,V**	TR,V	TR,V	TR,V	TR,V	-	-
Situational awareness: (Data w/voice secondary)								
How long must we hold this casualty?[f]	-	D,(V)	D,(V)	D,(V)	-	-	-	**D,(V)**
Are we running low on supplies?[f]	-	D,(V)	D,(V)	D,(V)	-	-	**D,V**	D,(V)
More casualties coming in? When, how many?[f]	-	D,(V)	D,(V)	D,(V)	-	-	-	**D,(V)**

a. This information is best supplied by data, whether over airwaves or on disc or dogtag.
b. We assume AFMIC or disease vector response teams will provide prevention information as data.
c. Immediate knowledge of CBR is essential.
d. We assume that training is essential for quick independent response, or for use of voice consults.
e. We assume that for telepsychiatry, video would be too expensive.
f. In some circumstances, this kind of information will affect treatment.

Appendix G: Identifying clinical information and communication requirements

To translate clinical requirements for information and communication into a set of technical specifications, we needed to estimate the frequency of need and the duration of use. To quantify requirements in this way, we identified specific tasks that would benefit from telementoring and/or teleconsultation. We did this based on our focus groups and interviews with clinical experts, and descriptive analyses of the echelon 1 and 2 Clinical Data Base—currently being developed at the Directorate of Combat and Doctrine Development, U.S. Army Medical Department Center and School (AMEDD).

Methodology

Using the AMEDD database, we developed lists of all the tasks performed at each field medical node:

- Site of injury
- Site of injury, supplemented[96]
- Battalion Aid Station (BAS)
- Medical Battalion (basically, the surgical company).[97]

96. *Site of injury, supplemented,* refers to the unit corpsman functioning in the limited and perhaps transitional scenarios. Given that they do not have the support of a BAS, STP, or surgical company, corpsmen would be required to perform an extended range of procedures.

97. At this time, the table of equipment for the Shock Trauma Platoon (STP) is still being developed. Because their mission is to supplement and augment the BAS, as well as transport casualties to the surgical company, we assume that STPs perform tasks similar to the BAS (even though they will potentially be equipped to do more advanced trauma life support than the BAS). In addition, some of their tasks may fall under the Medical Battalion heading.

From each list, we selected those tasks performed by the highest trained individuals. We assume that these people will be the initiators of telementoring or teleconsultation at their node.[98] In addition, we limited our scope of the medical battalion to those tasks performed on casualties requiring surgery at the surgical company.[99]

Based on our focus groups and interviews with corpsmen and military physicians at I MEF and II MEF, we took these lists of tasks and determined those tasks most likely to require telementoring and/or teleconsulting at each medical node. This subset is not meant to be exhaustive, nor is it meant to suggest that unit corpsmen, IDCs, PAs, or MOs would necessarily initiate communication each time they are confronted with these tasks or the potential to perform such tasks. Rather, we postulate that these subsets represent the more difficult tasks faced by a particular provider, or those tasks that might preferably be performed by a specialist not available at the treatment site. Therefore, we believe it is likely that the provider might initiate voice communications when treating a casualty requiring these types of procedures.

Once the tasks were identified, we merged the task codes with the Time Task Treater (TTT) file to identify which patient codes (PCs) required these tasks. And finally, we determined the probability of the casualty type occurring.[100]

98. These individuals consist of the corpsman at the site of injury; the medical officer (MO), physician's assistant (PA), or independent duty corpsman (IDC) at the BAS and STP; and MOs at the surgical companies.

99. Patient codes requiring surgery at echelon II were determined by clinical experts in conjunction with the development of the data at AMEDD.

100. To determine the probability associated with a PC, we used the Notional MEF Worst Case Scenario Patient Flow for the Marine Corps. These data were provided by Naval Health Research Center (NHRC). Using these data, we estimated a patient category distribution, which we then applied to our limited, transitional, and sustained casualty estimates.

Results

To estimate the frequency of calls that occur we look at two types of tasks:

- First, those *medical procedures* that are associated with the treatment of particular PCs or complications arising from those PCs (such as emergency cricothyroidotomy and management of a tourniquet).
- Second, those tasks that require making an *assessment* (either an initial assessment, diagnosis, or IV assessments) that affect nearly all of the casualties.

For the first set of tasks, *medical procedures,* we assume that for each casualty that *potentially* requires these types of treatment, voice communication would be initiated. For example, 0.93 percent of all casualties will suffer from a severe face wound, jaws and neck open lacerated with associated fractures (excluding spinal fractures) and airway obstruction (PC 017). Only 10 percent of these individuals will require an emergency cricothyroidotomy (one of the tasks we identified as a telementoring/teleconsultation task). But we assume that voice communication will be initiated for the entire 0.93 percent of casualties with PC 017, rather than just the 0.09 percent, representing PC 017 casualties who receive a cricothyroidotomy. By summing the probability that a casualty type (represented by PC) requiring one of these potentially voice-assisted treatments (or tasks) would occur, we arrive at a conservative estimate of the probability that voice communication will be initiated to assist with treatment.[101] This conservative estimate allows us to control for surge requirements.

Based on these methods, we found that, in the sustained scenario, the frequency of voice communications being initiated for this set of tasks (*medical procedures*) was equal to:

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101. Note that some PCs are counted more than once. This is because we treat each task as a potential telementoring or teleconsulting event. For example, if a PC requires or has the possibility of requiring two of these tasks, then the probability of that PC occurring is counted twice in our calculation.

- Five percent of the total casualties, at the site of injury
- Thirty-three percent at the BAS/STP[102]
- Thirty-five percent at the surgical company.

In the limited and sustained scenarios, we estimate that the frequency of voice communications associated with *medical procedure* tasks is equal to 30 percent of the total casualty population (see tables 15 through 18).

For the second set of tasks, *assessments,* we assumed that only some fraction of illnesses or injuries would be complicated enough to benefit from teleconsultation (voice). We estimated the percentage of casualties that require these types of assessments at the point of injury and the BAS. For estimation purposes, we assumed that 10 to 15 percent of these casualties' assessments would need to be supported by voice communications (see table 19).[103]

Finally, for the highly mobile surgical unit (HMSU), defined in chapter 3, we based our estimate of the frequency of calls on the percentage of casualties that require echelon II surgery. Seventeen percent of the total casualties fall into this category (see table 2). As a conservative estimate of HMSU's requirements, we assume that voice communications would be initiated for each surgical case (that is, 17 percent of total casualties in the transitional scenario).

102.Because the STP is still being defined, we treat the BAS and the STP as a single entity. This is based on our assumption that the STP will function as an augment to the BAS, sometimes will replace a BAS that moves forward, and other times will transport casualties from the BAS to the surgical company.

103.Interviews with those in the civilian emergency medical systems indicated that the majority of telementoring or teleconsultation occur in instances of multiple injuries. These cases represent a group of injuries for which the emergency medics (mainly with basic or advanced TLS training) do not have a set approach and are, therefore, the most challenging. Multiple injury wounds are incurred by about 5 percent of total casualties. We assume that all of these will require voice consultation for assessments, and an additional 5 percent for sustained and 10 percent for unit corpsman in the limited and transitional scenarios.

Table 15. Echelon 1a (self, buddy, HM)—medical procedures that might benefit from telementoring and/or teleconsulting

PC	Percentage of total casualties	Task[a]	Task description	Minutes	Times required on initial day	Percentage of patients requiring task
017	0.93	007	Emergency cricothyroidotomy (Phys)	6	1	10
019	0.07	007	Emergency cricothyroidotomy (Phys)	6	1	10
027	0.02	Z027	Cardio arrest resuscitation (Phys)	30	1	100
029	0.12	Z027	Cardio arrest resuscitation (Phys)	30	1	100
069	0.10	A6	Apply tourniquet	3	1	100
070	0.12	A6	Apply tourniquet	3	1	100
071	0.03	A6	Apply tourniquet	3	1	100
071	0.03	Z027	Cardio arrest resuscitation (Phys)	30	1	3
088	0.75	Z027	Cardio arrest resuscitation (Phys)	30	1	1
098	0.00	Z027	Cardio arrest resuscitation (Phys)	30	1	3
123	0.57	A6	Apply tourniquet	3	1	100
130	0.79	A6	Apply tourniquet	3	1	100
138	0.07	Z027	Cardio arrest resuscitation (Phys)	30	1	1
144	0.08	A6	Apply tourniquet	3	1	100
145	0.18	A6	Apply tourniquet	3	1	100
146	0.04	A6	Apply tourniquet	3	1	100
147	0.07	A6	Apply tourniquet	3	1	100
165	0.60	A6	Apply tourniquet	3	2	100
309	0.68	296	Psychological assessment interview	20	1	100
317	0.21	296	Psychological assessment interview	20	1	100
Total	**5.46**					

a. This does not include task 048—assess IV requirements.

Table 16. Echelon 1b (BAS)—medical procedures that might benefit from telementoring and/or teleconsulting

PC	Category	Percentage of total casualties	Task	Task description	Minutes	Times task required on initial day	Percentage of patients requiring task
001	Head	0.04	Z014	Intubation (Phys)	5	1	40
003	Head	0.05	Z014	Intubation (Phys)	5	1	100
003	Head	0.05	Z027	Cardio arrest resuscitation (Phys)	30	1	5
004	Head	0.13	Z014	Intubation (Phys)	5	1	10
005	Head	0.02	Z014	Intubation (Phys)	5	1	50
006	Head	0.03	Z014	Intubation (Phys)	5	1	50
007	Head	0.00	Z014	Intubation (Phys)	5	1	80
009	Head	0.45	Z014	Intubation (Phys)	5	1	80
011	CV	0.00	Z014	Intubation (Phys)	5	1	15
011	CV	0.00	Z027	Cardio arrest resuscitation (Phys)	30	1	10
015	Head	0.10	007	Emergency cricothyroidotomy (Phys)	6	1	30
017	Head	0.93	007	Emergency cricothyroidotomy (Phys)	6	1	90
019	Head	0.07	007	Emergency cricothyroidotomy (Phys)	6	1	40
019	Head	0.07	Z014	Intubation (Phys)	5	1	50
027	Spine	0.02	007	Emergency cricothyroidotomy (Phys)	6	1	20
029	Spine	0.12	007	Emergency cricothyroidotomy (Phys)	6	1	100
029	Spine	0.12	Z014	Intubation (Phys)	5	1	80
029	Spine	0.12	Z027	Cardio arrest resuscitation (Phys)	30	1	6
039	Burns	0.05	007	Emergency cricothyroidotomy (Phys)	6	1	20
049	Upper Limb	0.07	100	Closed reduction of fractured radius and ulna	20	1	100

Table 16. Echelon 1b (BAS)—medical procedures that might benefit from telementoring and/or teleconsulting (continued)

PC	Category	Percentage of total casualties	Task	Task description	Minutes	Times task required on initial day	Percentage of patients requiring task
064	Upper Limb	0.05	453	Closed reduction of dislocation	15	1	100
065	Upper Limb	0.00	453	Closed reduction of dislocation	15	1	5
067	Upper Limb	0.00	453	Closed reduction of dislocation	15	1	5
068	Upper Limb	0.02	099	Closed reduction (finger, thumb, toe)	8	1	100
068	Upper Limb	0.02	453	Closed reduction of dislocation	15	1	100
079	Burns	0.12	063	Venous cutdown (Phys)	15	1	100
081	Thorax	0.07	221	Pericardiocentesis	15	1	5
081	Thorax	0.07	Z042	Insert chest tube (Phys)	10	1	20
082	Thorax	0.15	221	Pericardiocentesis	15	1	5
083	Thorax	0.00	221	Pericardiocentesis	15	1	5
083	Thorax	0.00	Z014	Intubation (Phys)	5	1	80
083	Thorax	0.00	Z027	Cardio arrest resuscitation (Phys)	30	1	4
083	Thorax	0.00	Z042	Insert chest tube (Phys)	10	1	50
084	Thorax	0.02	221	Pericardiocentesis	15	1	5
084	Thorax	0.02	Z042	Insert chest tube (Phys)	10	1	50
086	Sup/Soft Tissue	0.68	108	Minor surgical procedure (debride/suture/incision	30	1	100
087	Thorax	0.85	221	Pericardiocentesis	15	1	5
087	Thorax	0.85	Z014	Intubation (Phys)	5	1	40
087	Thorax	0.85	Z042	Insert chest tube (Phys)	10	1	50
088	Thorax	0.75	221	Pericardiocentesis	15	1	5
088	Thorax	0.75	Z014	Intubation (Phys)	5	1	25
088	Thorax	0.75	Z042	Insert chest tube (Phys)	10	1	100
092	Burns	0.04	Z027	Cardio arrest resuscitation (Phys)	30	1	1
094	Burns	0.08	Z027	Cardio arrest resuscitation (Phys)	30	1	2
100	Abd & Pelvis	0.16	Z027	Cardio arrest resuscitation (Phys)	30	1	2
101	Abd & Pelvis	0.63	Z027	Cardio arrest resuscitation (Phys)	30	1	1

Table 16. Echelon 1b (BAS)—medical procedures that might benefit from telementoring and/or teleconsulting (continued)

PC	Category	Percentage of total casualties	Task	Task description	Minutes	Times task required on initial day	Percentage of patients requiring task
103	Abd & Pelvis	0.12	Z027	Cardio arrest resuscitation (Phys)	30	1	5
105	Abd & Pelvis	0.11	Z027	Cardio arrest resuscitation (Phys)	30	1	8
106	Abd & Pelvis	0.00	Z027	Cardio arrest resuscitation (Phys)	30	1	3
108	Abd & Pelvis	0.02	Z027	Cardio arrest resuscitation (Phys)	30	1	3
112	Abd & Pelvis	0.02	Z027	Cardio arrest resuscitation (Phys)	30	1	3
114	Abd & Pelvis	0.26	Z027	Cardio arrest resuscitation (Phys)	30	1	4
115	Abd & Pelvis	0.20	Z027	Cardio arrest resuscitation (Phys)	30	1	1
122	Sup/Soft Tissue	0.65	108	Minor surgical procedure (debride/suture/incision	30	1	100
129	Sup/Soft Tissue	1.60	108	Minor surgical procedure (debride/suture/incision	30	1	100
131	Lower Limbs	3.25	Z027	Cardio arrest resuscitation (Phys)	30	1	1
135	Sup/Soft Tissue	0.45	108	Minor surgical procedure (debride/suture/incision	30	1	100
140	Lower Limbs	0.00	453	Closed reduction of dislocation	15	1	50
143	Lower Limbs	0.00	099	Closed reduction (finger, thumb, toe)	8	1	100
143	Lower Limbs	0.00	359	Induce local anesthesia (Gen Surg)	5	1	50
143	Lower Limbs	0.00	453	Closed reduction of dislocation	15	1	100
145	Lower Limbs	0.18	Z027	Cardio arrest resuscitation (Phys)	30	1	1
146	Lower Limbs	0.04	Z027	Cardio arrest resuscitation (Phys)	30	1	2
147	Lower Limbs	0.07	Z027	Cardio arrest resuscitation (Phys)	30	1	2
156	Misc	0.27	108	Minor surgical procedure (debride/suture/incision	30	1	100
159	MIW	0.24	007	Emergency cricothyroidotomy (Phys)	6	1	10
159	MIW	0.24	221	Pericardiocentesis	15	1	5
159	MIW	0.24	Z014	Intubation (Phys)	5	1	80
159	MIW	0.24	Z027	Cardio arrest resuscitation (Phys)	30	1	5
159	MIW	0.24	Z042	Insert chest tube (Phys)	10	1	100
160	MIW	0.14	Z014	Intubation (Phys)	5	1	80
160	MIW	0.14	Z027	Cardio arrest resuscitation (Phys)	30	1	7

Table 16. Echelon 1b (BAS)—medical procedures that might benefit from telementoring and/or teleconsulting (continued)

PC	Category	Percentage of total casualties	Task	Task description	Minutes	Times task required on initial day	Percentage of patients requiring task
161	MIW	0.08	Z027	Cardio arrest resuscitation (Phys)	30	1	7
162	MIW	0.14	Z027	Cardio arrest resuscitation (Phys)	30	1	6
163	MIW	0.11	Z027	Cardio arrest resuscitation (Phys)	30	1	10
164	MIW	0.05	Z014	Intubation (Phys)	5	1	80
164	MIW	0.05	Z027	Cardio arrest resuscitation (Phys)	30	1	7
165	MIW	0.60	Z014	Intubation (Phys)	5	1	80
165	MIW	0.60	Z027	Cardio arrest resuscitation (Phys)	30	1	5
166	MIW	0.06	221	Pericardiocentesis	15	1	5
166	MIW	0.06	Z027	Cardio arrest resuscitation (Phys)	30	1	2
166	MIW	0.06	Z042	Insert chest tube (Phys)	10	1	50
167	MIW	0.04	221	Pericardiocentesis	15	1	5
167	MIW	0.04	Z027	Cardio arrest resuscitation (Phys)	30	1	5
167	MIW	0.04	Z042	Insert chest tube (Phys)	10	1	50
168	MIW	0.07	221	Pericardiocentesis	15	1	5
168	MIW	0.07	Z027	Cardio arrest resuscitation (Phys)	30	1	4
168	MIW	0.07	Z042	Insert chest tube (Phys)	10	1	50
169	MIW	0.05	221	Pericardiocentesis	15	1	5
169	MIW	0.05	Z027	Cardio arrest resuscitation (Phys)	30	1	8
169	MIW	0.05	Z042	Insert chest tube (Phys)	10	1	50
170	MIW	0.05	221	Pericardiocentesis	15	1	5
170	MIW	0.05	Z027	Cardio arrest resuscitation (Phys)	30	1	5
170	MIW	0.05	Z042	Insert chest tube (Phys)	10	1	50
171	MIW	0.82	221	Pericardiocentesis	15	1	5
171	MIW	0.82	Z042	Insert chest tube (Phys)	10	1	50
175	MIW	0.52	Z027	Cardio arrest resuscitation (Phys)	30	1	6
176	MIW	0.01	Z027	Cardio arrest resuscitation (Phys)	30	1	7

Table 16. Echelon 1b (BAS)—medical procedures that might benefit from telementoring and/or teleconsulting (continued)

PC	Category	Percentage of total casualties	Task	Task description	Minutes	Times task required on initial day	Percentage of patients requiring task
177	MIW	0.01	Z027	Cardio arrest resuscitation (Phys)	30	1	8
178	MIW	0.22	Z027	Cardio arrest resuscitation (Phys)	30	1	5
179	MIW	0.21	Z027	Cardio arrest resuscitation (Phys)	30	1	1
180	MIW	0.26	Z027	Cardio arrest resuscitation (Phys)	30	1	2
181	MIW	0.19	Z027	Cardio arrest resuscitation (Phys)	30	1	5
182	MIW	0.61	007	Emergency cricothyroidotomy (Phys)	6	1	10
182	MIW	0.61	221	Pericardiocentesis	15	1	5
182	MIW	0.61	Z027	Cardio arrest resuscitation (Phys)	30	1	5
182	MIW	0.61	Z042	Insert chest tube (Phys)	10	1	80
183	MIW	0.80	221	Pericardiocentesis	15	1	5
183	MIW	0.80	Z014	Intubation (Phys)	5	1	80
183	MIW	0.80	Z027	Cardio arrest resuscitation (Phys)	30	1	3
183	MIW	0.80	Z042	Insert chest tube (Phys)	10	1	80
184	MIW	0.09	221	Pericardiocentesis	15	1	5
184	MIW	0.09	Z014	Intubation (Phys)	5	1	80
184	MIW	0.09	Z027	Cardio arrest resuscitation (Phys)	30	1	3
184	MIW	0.09	Z042	Insert chest tube (Phys)	10	1	80
185	MIW	0.09	221	Pericardiocentesis	15	1	5
185	MIW	0.09	Z027	Cardio arrest resuscitation (Phys)	30	1	16
185	MIW	0.09	Z042	Insert chest tube (Phys)	10	1	100
192	Env	0.03	Z027	Cardio arrest resuscitation (Phys)	30	1	100
193	Env	0.00	Z014	Intubation (Phys)	5	1	50
196	Surgical	0.02	Z027	Cardio arrest resuscitation (Phys)	30	1	2
204	Derm	0.14	108	Minor surgical procedure (debride/suture/incision	30	1	100
239	Respiratory	0.44	Z027	Cardio arrest resuscitation (Phys)	30	1	10
258	CV	0.15	Z027	Cardio arrest resuscitation (Phys)	30	1	10

Table 16. Echelon 1b (BAS)—medical procedures that might benefit from telementoring and/or teleconsulting (continued)

PC	Category	Percentage of total casualties	Task	Task description	Minutes	Times task required on initial day	Percentage of patients requiring task
259	CV	0.00	Z014	Intubation (Phys)	5	1	5
259	CV	0.00	Z027	Cardio arrest resuscitation (Phys)	30	1	5
264	Infectious/Para	0.01	Z027	Cardio arrest resuscitation (Phys)	30	1	10
265	Misc	0.10	Z014	Intubation (Phys)	5	1	50
265	Misc	0.10	Z027	Cardio arrest resuscitation (Phys)	30	1	10
266	Misc	0.14	Z014	Intubation (Phys)	5	1	30
266	Misc	0.14	Z027	Cardio arrest resuscitation (Phys)	30	1	10
301	Neuropsych	0.06	296	Psychological assessment interview	20	1	100
302	Neuropsych	0.13	296	Psychological assessment interview	20	1	100
303	Neuropsych	0.05	296	Psychological assessment interview	20	1	100
306	Neuropsych	0.28	296	Psychological assessment interview	20	1	100
307	Neuropsych	0.71	296	Psychological assessment interview	20	1	100
308	Neuropsych	0.04	296	Psychological assessment interview	20	1	100
309	Neuropsych	0.68	296	Psychological assessment interview	20	1	100
316	Neuropsych	0.12	296	Psychological assessment interview	20	1	100
317	Neuropsych	0.21	296	Psychological assessment interview	20	1	100
Total		**33.41**					

Table 17. Echelon 2 (surgical company—medical procedures that might benefit from telementoring and/or teleconsulting)

Ech	F	PC	Category	Percentage of total casualties	Task	Task description	Min	Init	Recur	Percentage of patients
2F	O	017	Head	0.93	488	Repair wound neck structures open (otolary/gen surg)	68	1	0	50
2F	O	019	Head	0.07	488	Repair wound neck structures open (otolary/gen surg)	68	1	0	100
2		045	Upper Limb	0.01	105	Doppler assessment (ortho/gen surg)	2	1	0	100
2F	E	045	Upper Limb	0.01	105	Doppler assessment (ortho/gen surg)	2	1	0	100
2F	R	045	Upper Limb	0.01	105	Doppler assessment (ortho/gen surg)	2	4	2	100
2F	O	045	Upper Limb	0.01	461	Debride wound (ortho/gen surg)	90	1	0	10
2F	O	071	Upper Limb	0.03	461	Debride wound (ortho/gen surg)	90	1	0	100
2F	O	087	Thorax	0.85	494	Thoracotomy (thor/gen surg)	20	1	0	100
2F	O	088	Thorax	0.75	494	Thoracotomy (thor/gen surg)	20	1	0	100
2F	O	106	Abd & Pelvis	0.00	508	Complete nephrectomy (urol/gen surg)	30	1	0	100
2F	O	108	Abd & Pelvis	0.02	509	Repair urinary bladder (urol/gen surg)	45	1	0	100
2F	O	109	Abd & Pelvis	0.07	509	Repair urinary bladder (urol/gen surg)	45	1	0	100
2F	O	114	Abd & Pelvis	0.24	509	Repair urinary bladder (urol/gen surg)	45	1	0	100
2		124	Lower Limbs	2.13	105	Doppler assessment (ortho/gen surg)	2	1	0	150
2F	E	124	Lower Limbs	2.13	105	Doppler assessment (ortho/gen surg)	2	1	0	150
2F	R	124	Lower Limbs	2.13	105	Doppler assessment (ortho/gen surg)	2	1	0	150
2		131	Lower Limbs	3.22	105	Doppler assessment (ortho/gen surg)	2	1	0	40
2F	E	131	Lower Limbs	3.22	105	Doppler assessment (ortho/gen surg)	2	1	0	40
2F	R	131	Lower Limbs	3.22	105	Doppler assessment (ortho/gen surg)	2	2	2	150
2F	O	131	Lower Limbs	3.22	461	Debride wound (ortho/gen surg)	90	1	0	150
2		137	Lower Limbs	1.27	105	Doppler assessment (ortho/gen surg)	2	1	0	80
2F	E	137	Lower Limbs	1.27	105	Doppler assessment (ortho/gen surg)	2	1	0	80

Table 17. Echelon 2 (surgical company—medical procedures that might benefit from telementoring and/or teleconsulting) (con-

Ech	F	PC	Category	Percentage of total casualties	Task	Task description	Min	Init	Recur	Percentage of patients
2F	R	137	Lower Limbs	1.27	105	Doppler assessment (ortho/gen surg)	2	4	4	100
2F	O	137	Lower Limbs	1.27	461	Debride wound (ortho/gen surg)	90	1	0	100
2		138	Lower Limbs	0.07	105	Doppler assessment (ortho/gen surg)	2	1	0	100
2F	E	138	Lower Limbs	0.07	105	Doppler assessment (ortho/gen surg)	2	1	0	100
2		139	Lower Limbs	0.06	105	Doppler assessment (ortho/gen surg)	2	1	0	100
2F	E	139	Lower Limbs	0.06	105	Doppler assessment (ortho/gen surg)	2	1	0	100
2F	R	139	Lower Limbs	0.06	105	Doppler assessment (ortho/gen surg)	2	1	0	100
2F	O	139	Lower Limbs	0.06	467	Fasciotomy (ortho/gen surg)	15	1	0	100
2F	O	146	Lower Limbs	0.04	461	Debride wound (ortho/gen surg)	90	1	0	100
2F	O	147	Lower Limbs	0.07	461	Debride wound (ortho/gen surg)	90	1	0	100
2F	O	159	MIW	0.20	494	Thoracotomy (thor/gen surg)	20	1	0	100
2F	O	161	MIW	0.07	508	Complete nephrectomy (urol/gen surg)	30	1	0	100
2F	O	162	MIW	0.13	509	Repair urinary bladder (urol/gen surg)	45	1	0	100
2F	O	165	MIW	0.59	461	Debride wound (ortho/gen surg)	90	1	0	100
2F	O	168	MIW	0.06	509	Repair urinary bladder (urol/gen surg)	45	1	0	100
2F	E	171	MIW	0.82	105	Doppler assessment (ortho/gen surg)	2	1	0	200
2F	R	171	MIW	0.82	105	Doppler assessment (ortho/gen surg)	2	2	0	200
2F	O	172	MIW	0.04	509	Repair urinary bladder (urol/gen surg)	45	1	0	100
2F	E	175	MIW	0.47	105	Doppler assessment (ortho/gen surg)	2	1	0	100
2F	R	175	MIW	0.47	105	Doppler assessment (ortho/gen surg)	2	2	0	100
2F	O	176	MIW	0.00	508	Complete nephrectomy (urol/gen surg)	30	1	0	100
2F	O	177	MIW	0.01	509	Repair urinary bladder (urol/gen surg)	45	1	0	100
2F	E	178	MIW	0.22	105	Doppler assessment (ortho/gen surg)	2	2	0	200
2F	R	178	MIW	0.22	105	Doppler assessment (ortho/gen surg)	2	2	0	100
2F	O	179	MIW	0.21	461	Debride wound (ortho/gen surg)	90	1	0	100
2F	O	179	MIW	0.21	509	Repair urinary bladder (urol/gen surg)	45	1	0	100

Table 17. Echelon 2 (surgical company—medical procedures that might benefit from telementoring and/or teleconsulting) (con-

Ech	F	PC	Category	Percentage of total casualties	Task	Task description	Min	Init	Recur	Percentage of patients
2		180	MIW	0.26	105	Doppler assessment (ortho/gen surg)	2	1	0	90
2F	E	180	MIW	0.26	105	Doppler assessment (ortho/gen surg)	2	2	0	100
2F	R	180	MIW	0.26	105	Doppler assessment (ortho/gen surg)	2	2	0	200
2		180	MIW	0.26	106	Escharotomy w/o gen anesth (gen surg)	20	2	0	50
2F	R	182	MIW	0.61	105	Doppler assessment (ortho/gen surg)	2	2	2	200
2F	O	182	MIW	0.60	461	Debride wound (ortho/gen surg)	90	1	0	100
2F	O	184	MIW	0.09	509	Repair urinary bladder (urol/gen surg)	45	1	0	100
2F	O	185	MIW	0.05	508	Complete nephrectomy (urol/gen surg)	30	1	0	100
Total[a]				**34.77**						

a. (Bold entries not in ttt.sd2).

Table 18. Echelon 1a—supplemental (self, buddy, HM in limited or transitional scenario)—medical procedures that might benefit from telementoring and/or teleconsulting

PC	Category	Percentage of total casualties	Task	Task description	Minutes	Times task required (1st day)	Times task required (recurring days)	Percentage of patients requiring task
001	Head	0.04	Z014	Intubation (Phys)	5	1	0	40
003	Head	0.05	Z014	Intubation (Phys)	5	1	0	100
004	Head	0.13	Z014	Intubation (Phys)	5	1	0	50
005	Head	0.02	Z014	Intubation (Phys)	5	1	0	50
006	Head	0.03	Z014	Intubation (Phys)	5	1	0	50
007	Head	0	Z014	Intubation (Phys)	5	1	0	80
009	Head	0.45	Z014	Intubation (Phys)	5	1	0	80
011	CV	0	Z014	Intubation (Phys)	5	1	0	15
014	Sup/Soft Tissue	0.27	108	Minor surgical procedure (debride/suture/incision	30	1	0	100
014	Sup/Soft Tissue	0.27	359	Induce local anesthesia (Gen Surg)	5	1	0	100
017	Head	0.93	007	Emergency cricothyroidotomy (Phys)	6	1	0	10
019	Head	0.07	Z014	Intubation (Phys)	5	1	0	50
019	Head	0.07	007	Emergency cricothyroidotomy (Phys)	6	1	0	10
020	Sup/Soft Tissue	0.5	108	Minor surgical procedure (debride/suture/incision	30	1	0	100
027	Spine	0.02	Z042	Insert chest tube (Phys)	10	1	0	100
027	Spine	0.02	Z027	Cardio arrest resuscitation (Phys)	30	1	0	100
029	Spine	0.12	Z014	Intubation (Phys)	5	1	0	80
029	Spine	0.12	Z027	Cardio arrest resuscitation (Phys)	30	1	0	100
038	Burns	0.2	108	Minor surgical procedure (debride/suture/incision	30	1	1	100
049	Upper Limb	0.07	100	Closed reduction of fractured radius and ulna	20	1	0	100
064	Upper Limb	0.05	453	Closed reduction of dislocation	15	1	0	100
065	Upper Limb	0	453	Closed reduction of dislocation	15	1	0	5
067	Upper Limb	0	453	Closed reduction of dislocation	15	1	0	5
068	Upper Limb	0.02	099	Closed reduction (finger, thumb, toe)	8	1	0	100
068	Upper Limb	0.02	453	Closed reduction of dislocation	15	1	0	100

Table 18. Echelon 1a—supplemental (self, buddy, HM in limited or transitional scenario)—medical procedures that might benefit from telementoring and/or teleconsulting (continued)

PC	Category	Percentage of total casualties	Task	Task description	Minutes	Times task required (1st day)	Times task required (recurring days)	Percentage of patients requiring task
069	Upper Limb	0.1	A6	Apply tourniquet	3	1	0	100
070	Upper Limb	0.12	A6	Apply tourniquet	3	1	0	100
071	Upper Limb	0.03	063	Venous cutdown (Phys)	15	1	0	50
071	Upper Limb	0.03	A6	Apply tourniquet	3	1	0	100
071	Upper Limb	0.03	Z027	Cardio arrest resuscitation (Phys)	30	1	0	3
077	Burns	0.19	108	Minor surgical procedure (debride/suture/incision	30	1	0	100
078	Burns	0.17	108	Minor surgical procedure (debride/suture/incision	30	1	1	100
079	Burns	0.12	063	Venous cutdown (Phys)	15	1	0	100
081	Thorax	0.07	221	Pericardiocentesis	15	1	0	5
081	Thorax	0.07	Z042	Insert chest tube (Phys)	10	1	0	20
082	Thorax	0.15	221	Pericardiocentesis	15	1	0	5
083	Thorax	0	221	Pericardiocentesis	15	1	0	5
083	Thorax	0	Z014	Intubation (Phys)	5	1	0	80
083	Thorax	0	Z042	Insert chest tube (Phys)	10	1	0	50
084	Thorax	0.02	221	Pericardiocentesis	15	1	0	5
084	Thorax	0.02	Z014	Intubation (Phys)	5	1	0	10
084	Thorax	0.02	Z042	Insert chest tube (Phys)	10	1	0	50
086	Sup/Soft Tissue	0.68	108	Minor surgical procedure (debride/suture/incision	30	1	0	100
087	Thorax	0.85	221	Pericardiocentesis	15	1	0	5
087	Thorax	0.85	Z014	Intubation (Phys)	5	1	0	60
087	Thorax	0.85	Z042	Insert chest tube (Phys)	10	1	0	50
088	Thorax	0.75	221	Pericardiocentesis	15	1	0	5
088	Thorax	0.75	Z014	Intubation (Phys)	5	1	0	25
088	Thorax	0.75	Z042	Insert chest tube (Phys)	10	1	0	100
088	Thorax	0.75	Z027	Cardio arrest resuscitation (Phys)	30	1	0	1
093	Burns	0.05	108	Minor surgical procedure (debride/suture/incision	30	1	1	100

Table 18. Echelon 1a—supplemental (self, buddy, HM in limited or transitional scenario)—medical procedures that might benefit from telementoring and/or teleconsulting (continued)

PC	Category	Percentage of total casualties	Task	Task description	Minutes	Times task required (1st day)	Times task required (recurring days)	Percentage of patients requiring task
094	Burns	0.08	Z014	Intubation (Phys)	5	1	0	100
097	Sup/Soft Tissue	0.39	108	Minor surgical procedure (debride/suture/incision	30	1	0	100
098	Abdomen & Pelvis	0	Z027	Cardio arrest resuscitation (Phys)	30	1	0	3
100	Abdomen & Pelvis	0.16	063	Venous cutdown (Phys)	15	1	0	30
103	Abdomen & Pelvis	0.12	063	Venous cutdown (Phys)	15	1	0	30
104	Abdomen & Pelvis	0.08	063	Venous cutdown (Phys)	15	1	0	30
105	Abdomen & Pelvis	0.11	063	Venous cutdown (Phys)	15	1	0	30
111	Sup/Soft Tissue	0.24	108	Minor surgical procedure (debride/suture/incision	30	1	0	100
111	Sup/Soft Tissue	0.24	258	Fecal impaction assess/remove	5	0	1	20
114	Abdomen & Pelvis	0.26	063	Venous cutdown (Phys)	15	1	0	30
122	Sup/Soft Tissue	0.65	108	Minor surgical procedure (debride/suture/incision	30	1	0	100
123	Lower Limbs	0.57	A6	Apply tourniquet	3	1	0	100
129	Sup/Soft Tissue	1.6	108	Minor surgical procedure (debride/suture/incision	30	1	0	100
130	Lower Limbs	0.79	A6	Apply tourniquet	3	1	0	100
135	Sup/Soft Tissue	0.53	108	Minor surgical procedure (debride/suture/incision	30	1	0	100
138	Lower Limbs	0.07	Z027	Cardio arrest resuscitation (Phys)	30	1	0	1
140	Lower Limb	0	453	Closed reduction of dislocation	15	1	0	50
143	Lower Limb	0	099	Closed reduction (finger, thumb, toe)	8	1	0	100
143	Lower Limb	0	359	Induce local anesthesia (Gen Surg)	5	1	0	50
143	Lower Limb	0	453	Closed reduction of dislocation	15	1	0	100
144	Lower Limbs	0.08	A6	Apply tourniquet	3	1	0	100
145	Lower Limbs	0.18	A6	Apply tourniquet	3	1	0	100
146	Lower Limbs	0.04	A6	Apply tourniquet	3	1	0	100
147	Lower Limbs	0.07	A6	Apply tourniquet	3	1	0	100
152	Burns	0.04	108	Minor surgical procedure (debride/suture/incision	30	1	0	100
153	Burns	0.17	108	Minor surgical procedure (debride/suture/incision	30	1	0	100

Table 18. Echelon 1a—supplemental (self, buddy, HM in limited or transitional scenario)—medical procedures that might benefit from telementoring and/or teleconsulting (continued)

PC	Category	Percentage of total casualties	Task	Task description	Minutes	Times task required (1st day)	Times task required (recurring days)	Percentage of patients requiring task
156	Misc	0.27	108	Minor surgical procedure (debride/suture/incision	30	1	0	100
159	MIW	0.24	221	Pericardiocentesis	15	1	0	5
159	MIW	0.24	Z014	Intubation (Phys)	5	1	0	80
159	MIW	0.24	Z042	Insert chest tube (Phys)	10	1	0	100
160	MIW	0.14	Z014	Intubation (Phys)	5	1	0	80
164	MIW	0.05	Z014	Intubation (Phys)	5	1	0	80
165	MIW	0.6	A6	Apply tourniquet	3	2	0	100
165	MIW	0.6	Z014	Intubation (Phys)	5	1	0	
166	MIW	0.06	221	Pericardiocentesis	15	1	0	5
166	MIW	0.06	Z042	Insert chest tube (Phys)	10	1	0	50
167	MIW	0.04	221	Pericardiocentesis	15	1	0	5
167	MIW	0.04	Z042	Insert chest tube (Phys)	10	1	0	50
168	MIW	0.07	221	Pericardiocentesis	15	1	0	5
168	MIW	0.07	Z042	Insert chest tube (Phys)	10	1	0	50
169	MIW	0.05	221	Pericardiocentesis	15	1	0	5
169	MIW	0.05	Z042	Insert chest tube (Phys)	10	1	0	50
170	MIW	0.05	221	Pericardiocentesis	15	1	0	5
170	MIW	0.05	Z042	Insert chest tube (Phys)	10	1	0	50
171	MIW	0.82	221	Pericardiocentesis	15	1	0	5
171	MIW	0.82	Z014	Intubation (Phys)	5	1	0	2
171	MIW	0.82	Z042	Insert chest tube (Phys)	10	1	0	50
182	MIW	0.61	221	Pericardiocentesis	15	1	0	5
182	MIW	0.61	Z042	Insert chest tube (Phys)	10	1	0	80
183	MIW	0.8	221	Pericardiocentesis	15	1	0	5
183	MIW	0.8	Z014	Intubation (Phys)	5	1	0	80
183	MIW	0.8	Z042	Insert chest tube (Phys)	10	1	0	80

Table 18. Echelon 1a—supplemental (self, buddy, HM in limited or transitional scenario)—medical procedures that might benefit from telementoring and/or teleconsulting (continued)

PC	Category	Percentage of total casualties	Task	Task description	Minutes	Times task required (1st day)	Times task required (recurring days)	Percentage of patients requiring task
184	MIW	0.09	221	Pericardiocentesis	15	1	0	5
184	MIW	0.09	Z014	Intubation (Phys)	5	1	0	80
184	MIW	0.09	Z042	Insert chest tube (Phys)	10	1	0	80
185	MIW	0.09	221	Pericardiocentesis	15	1	0	5
185	MIW	0.09	Z014	Intubation (Phys)	5	1	0	100
185	MIW	0.09	Z042	Insert chest tube (Phys)	10	1	0	100
192	Env	0.03	Z014	Intubation (Phys)	5	1	0	100
193	Env	0	Z014	Intubation (Phys)	5	1	0	50
194	Env	0.03	258	Fecal impaction assess/remove	5	0	1	20
201	Sprains & Strains	0	258	Fecal impaction assess/remove	5	0	1	20
204	Derm	0.14	108	Minor surgical procedure (debride/suture/incision	30	1	0	100
256	Surgical	0.87	108	Minor surgical procedure (debride/suture/incision	30	1	0	20
256	Surgical	0.87	258	Fecal impaction assess/remove	5	0	1	20
259	CV	0	Z014	Intubation (Phys)	5	1	0	5
265	Misc	0.1	Z014	Intubation (Phys)	5	1	0	50
266	Misc	0.14	Z014	Intubation (Phys)	5	1	0	70
309	Neuropsychiatric	0.68	296	Psychological assessment interview	20	1	0	100
317	Neuropsychiatric	0.21	296	Psychological assessment interview	20	1	0	100
Total		**29.97**						

Table 19. Casualties requiring assessment that might benefit from teleconsultation and/or telementoring by task and site of care

Echelon/site of care	Number (fraction of total casualties) of casualties requiring tasks: 002[a]		048[b]		061[c]	
1A—point of injury	10,923	(97.1%)	4,645	(41.3%)	n/a	—
1B—BAS	11,202	(99.6%)	n/a	—	n/a	—
1A_sup—point of injury supplemented[d]	11,202	(99.6%)	10,172	(90.4%)	5,168	(46.0%)

a. Task 002—Assessment and evaluation of patient status.

b. Task 048—Assess IV requirements.

c. Task 061—IV infusion medicines (push, volutrol, admin).

d. "Supplemented" refers to point of injury in the limited and transitional scenarios. There is no BAS, or surgical company; therefore, the tasks that must be performed at the site of injury are assumed to be more extensive than those performed at the site of injury in the sustained scenario (with a BAS less than one mile away).

Glossary

AAAV	Advanced Amphibious Assault Vehicle
AFMIC	Armed Forces Medical Intelligence Center
AMAL	Authorized Medical Allowance List
AMEDD	U.S. Army Medical Department and School
ARPA	Advanced Research Project Agency
ARG	Amphibious Readiness Group
ATF	Amphibious Task Force
ATLS	Advanced Trauma Life Support
BAS	Battalion Aid Station
BLOS	Beyond Line of Sight
BLT	Battalion Landing Team
CASEST	The Marine Corps' official model for estimating number of casualties by rank and MOS—used for the purpose of identifying needs to replace troops under various combat scenarios.
CATF	Commander Amphibious Task Force
CCS	Hundred call seconds, a unit of measurement used by the telecommunication industry to measure the communication traffic in a telephone network.
CDMA	Code Division Multiple Access, a multiple access method which uses unique binary sequences or codes to allow many channels to share one communication circuit.

CJTF	Combined Joint Task Force
CLF	Commander Landing Force
COE	Common Operating Environment
C4IFTW	Command, Control, Communications, Computers, and Intelligence for the Warrior
CSMA	Carrier Sensing Multiple Access
CSS	Combat Service Support
CSS Enterprise	An initiative through the Commandant's Warfighting Lab to explore new concepts of combat service support
CWL	Commandant's Warfighting Laboratory
DAAS	Defense Automatic Addressing System
DAAS	Defense Automatic Addressing System
DAMA	Demand Assigned Multiple Access, a process in which a communication channel is shared among many users. The channel is temporarily assigned to a user upon his demand for the duration of the communication session only.
DASC	Direct Air Support Central—ensures coordinated aviation support to the MAGTF
DEPMEDS	Deployable Medical Systems. This provides data on 339 casualty conditions, including the probability distribution of conditions associated with an estimated casualty stream.
DIA	Defense Intelligence Agency
DII	Defense Information Infrastructure

Direct Sequence	A spread spectrum technique that uses pseudorandom codes to spread the communication signal
DISA	Defense Information System Agency
DSN	Defense Switched Network
E1	A basic unit of measurement capacity for international transmission carriers (2,048 Kbps). It is the equivalent of the T1 rate in North America.
FSSG	Force Service Support Group
GCCS	Global Command and Control System
GCSS	Global Combat Support System
HM	Hospital Corpsman
HMMWV	High Mobility, Multipurpose Wheeled Vehicle
HMSU	Highly Mobile Surgical Unit
INCA	Intelligence and Communications Architecture Project Office
INMARSAT	International Maritime Satellite
ISPG	Intelligence Programs Support Group
ITU	International Telecommunication Union
JTF	Joint Task Force
Kbps	Kilobits per second
LAN	Local Area Network
LCAC	Landing Craft Air Cushion
LHA	Amphibious Assault Ship–General Purpose
LHD	Amphibious Assault Ship–Multipurpose

LPD	Low Probability of Detection
LPE	Low Probability of Exploitation
LPI	Low Probability of Interception
MAD	Medical Anchor Desk
MATMO	Medical Advanced Technologies Management Office
Mbps	Megabits per second
MCCDC	Marine Corps Combat Development Command
MCSSD	Mobile Combat Service Support Detachment
MCSSD	Mobile Combat Service Support Detachment
MEDEVAC	Medical Evacuation
MEF	Marine Expeditionary Force
MEU	Marine Expeditionary Unit
MRSP	Medical Readiness Strategic Plan, 2001
MSSG	MEU Service Support Group
NEC^3	Naval Expeditionary Concept of Casualty Care workshop
NHRC	Naval Health Research Center
NMRDC	Naval Medical Research & Development Command
OMFTS	Operational Maneuver From the Sea
PCRTS	Primary Casualty Receiving and Treatment Ship

PCS	Personal Communication Systems. This is the new wireless communications services at the recently allocated 1.9GHz frequency band.
PDA	Personal Digital Assistants
PSM	Personnel Status Monitor. A device that keeps track of each troop's blood pressure, heart rate, and other vital signs
RTD	Return to duty
SMU	Sassy Management Unit
Spread Spectrum	A radio communication and radar technique that spreads a signal bandwidth over a much wider bandwidth for transmission and despreads the received signal to the original bandwidth at reception. This technique has been used in the military to provide secured communications.
STP	Shock Trauma Platoon
T1	A basic unit of measurement capacity for North American transmission carriers (1,544 Kbps). It is the equivalent of the international E1 rate.
TCIMS	Trauma Care Information Management System, a project at Advanced Research Project Agency (ARPA)
Teleconsulting	Process used when two physicians or a physician and physician's assistant discuss a casualty's condition to establish the best assessment and treatment
Telementoring	Process used when medical personnel with greater knowledge or experience guides a person with less knowledge who is assessing or treating a patient at a remote location

Telemedicine	Process used when any two medical personnel use communications to consult concerning a casualty
TMIP	Theater Medical Information Program, a Department of Defense Project currently run by the Navy Medical Information Management Center (NMIMC)
TMIS	Corps Level Theater Medical Information System, a project for Health Services Operations and Readiness Division by the SRA Corporation
TRAC^{2}ES	TRANSCOM Regulating Command & Control Evacuation System
TRANSCOM	United States Transportation Command
UAV	Unmanned Aerial Vehicle
USPACECOM	U.S. Space Command
Vanguard '96	Medical Science and Technology Game, sponsored by NMRDC
VTC	Video Teleconferencing
V-22	Osprey tilt-rotor aircraft
WDMET	Wound Data Munitions Effectiveness Team This team did extensive data collection and analysis concerning the distribution of wounds and illnesses during an 18-month period of the Vietnam War. The data set is unique because it attempted to account for all injuries and illnesses, including killed in action, not just those casualties that resulted in a hospital admission.

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